SCHOOL OF NANOSCIENCE AND NANOTECHNOLOGY

MAHATMA GANDHI UNIVERSITY

CURRICULUM STRUCTURE AND SYLLABI

(BASED ON OUTCOME BASED EDUCATION)

For the Programme,

M.Sc. Chemistry (Nanoscience and Nanotechnology)

(Under the CSS Regulations 2021 of Mahatma Gandhi University

w.e.f**. 2021** Admission Onwards)

PREFACE

I am happy to present the revised curricula and syllabi of the following M.Sc. Chemistry (Nanoscience and Nanotechnology) Programme of the School of Nanoscience and Nanotechnology according to the OBE concept (with effect from 2022 admission onwards) for favour of approval by the Faculty and Academic Council of the University.

The Board of Studies has restructured the curriculum as per the Outcome Based Education (OBE) system. OBE is an educational approach that bases each part of the educational system with respect to the goals set for the students. OBE aims to equip the students (learners)with knowledge, competency orientations required for achieving their goals when they depart the institution. Further OBE empowers students to choose what they would like to study and how they would like to study it. The teaching methodologies and the evaluation system are also modified in par with the outcome-based approach. The Programme Specific Outcomes (PSOs) and the Course Outcomes (COs) are presented in the syllabus. The PSOs and the COs are well correlated in the syllabus of each course.

The draft curricula and syllabi for the M.Sc. Chemistry (Nanoscience and Nanotechnology) Programme were discussed in a very effective manner in the Board of Studies of the School of Nanoscience and Nanotechnology. The Board of Studies has also modified the scheme, curricula and syllabi for the M.Sc. Programme in conformity with the Revised CSS Regulations 2020 by the Mahatma Gandhi University to suit the Credit and Semester System. The content of the syllabus has been modified significantly (around 20 % of the total content from the previous syllabus especially by adding new courses such as advanced courses in inorganic, organic and physical chemistry (second and third semesters), Design, synthesis and fabrication of Nanomaterials, Advanced quantum mechanics and Group theory (second semester), Applications of Nanotechnology, Nano biomedicine (third semester). Some advanced and interdisciplinary topics are added as electives also. Another salient feature of the revised curriculum is the inclusion of practical courses named Synthesis of Nanomaterials (second semester) and Characterization of Nanomaterials (third semester).

The BOS feels that appreciable updating could be done in keeping with the current developments and trends in chemistry education.

-sd- Prof.

(Chairman, Board of Studies of School of Nanoscience and Nanotechnology)

Members of the Board of Studies of School of Nanoscience and Nanotechnology

(vide UO No: 5435/AD A 7/2022/MGU Dated: 25.05.2022)

1. Prof. (Dr.) Sabu Thomas, Hon. Vice Chancellor & Director of School of Nanoscience and Nanotechnology.
2. Dr. Sreekala MS, Joint Director, School of Nanoscience and Nanotechnology.
3. Dr. Nandakumar Kalarikkal, School of Pure and Applied Physics.
4. Dr. Radhakrishnan EK, School of Biosciences.
5. Dr. Anitha C Kumar, School of Chemical Sciences.
6. Dr. Kuruvilla Joseph, IIST Thiruvananthapuram.
7. Dr. Sandhyarani, NIT Calicut.
8. Dr. Lissymol Jacob, SCTIMST, Thiruvananthapuram.
9. Dr. Anantharaman, CUSAT.
10. Dr. Deepthi Menon, AIMS Kochi.
11. Dr. Honey John, CUSAT.

Mahatma Gandhi University

Vision

‘’Mahatma Gandhi University envisions to excel in the field of higher education and cater to the scholastic and developmental needs of the individual, through continuous creation of critical knowledge base for the society’s sustained and inclusive growth.”

Mission

- To conduct and support undergraduate, postgraduate and research-level programmes of quality in different disciplines
- To foster teaching, research and extension activities for the creation of new knowledge for the development of society
- To help in the creation and development of manpower that would provide intellectual leadership to the community
- To provide skilled manpower to the professional, industrial and service sectors in the country so as to meet global demands.
- To help promote the cultural heritage of the nation and preserve the environmental sustainability and quality of life
- To cater to the holistic development of the region through academic leadership.

School of Nanoscience and Nanotechnology

Vision

•Quality education in Physics and Chemistry with specialization in Nanoscience and Nanotechnology for the creation of a vibrant and inclusive society.

Mission

- Generation, preservation and dissemination of knowledge in the frontier areas of science.
- Equip the students to build up a scientific career and contribute towards the national development.
- Foster collaboration with leading research institutions in knowledge production.
- Inculcate among students’ human values with global competence.

OBJECTIVES

School of Nanoscience & Nanotechnology, Mahatma Gandhi University would like to launch the M.Sc. Chemistry (Nanoscience and Nanotechnology) Program which has been designed to attract highly motivated science graduates. This program is intended to create highly skilled manpower in the field of Nanoscience and Nanotechnology. This program would admit 10 numbers of bright, highly motivated students with excellent academic record at the graduate level. The main objective of the program is to induce and cultivate an enhanced sense of research awareness and aptitude with perspectives on the Chemistry of nanomaterials. The final semester is fully dedicated to a six-month research lab or industrial dissertation. This will ensure a research career-oriented post-graduate degree course uplifting the student's prospect in the ever-advancing field of Nanoscience and Nanotechnology. Upon successful completion of the two years in the program, the candidates will be awarded a Master's Degree in Chemistry (Nanoscience and Nanotechnology) under the Faculty of Science of Mahatma Gandhi University.

DEFINITIONS

The **Program** refers to the previous concept of degree carried out in a time-bound academic period.

The **Course** means the curricular content for teaching and learning or seminar in a specific area or theme of knowledge.

The **Core Course** means a compulsory course in a subject related to a particular program.

The **Elective Course** means an optional course which can be selected from among a group of electives provided in the program.

SEMESTER SYSTEM

The M. Sc. Program will have four semesters. There shall be a minimum of 540 hours distributed over 90 working days in each semester spread over l8 five days working weeks.

Credit (C) is the unit by which a course is measured. It is the measure of total numbers of hours of training received in a course during a semester.

Grade means a letter symbol (e. g. A, B, C. etc.) which indicates the broad level of performance of a student in an answer/course/semester/program.

Weight is a numerical measure quantifying the comparative range of an answer or the comparative importance assigned to different components like theory (internal and external examinations) Internship, Dissertation etc.

Grade Point (G) is the weightage allotted to Grade letter.

Credit Point (C) refers to the product of number of credits of a course and grade point obtained by a student for a given course.

Semester Grade Point Average (SGPA) refers to the performance of the student in a given semester. SGPA is a weighted average based on the total credit points earned by a student in all the courses in the semester divided by the total number of credits offered in a semester. SGPA will be computed as and when a student completes all the required courses of a semester with a minimum required grade as per the respective curriculum.

Cumulative Grade Point Average (CGPA) refers to the performance of the student for all semesters of the program. CGPA is a weighted average based on the SGPA earned by a student in all semesters of the program and the total number of credits required in the program.

CGPA is calculated on the basis of SGPA with the minimum required SGPAs of all semesters may not be sufficient to obtain the minimum fixed CGPA for pass in the program.

Grade Point Average (GPA) is the value obtained by dividing the sum of the weighted grade points obtained by a student in an examination of a course in a semester by the total weightage taken in that examination. The grade point average shall be rounded off to two decimal places.

Preamble

Outcome Based Education (OBE) w.e.f. the Academic Year 2022-23 SCHOOL OF NANOSCIENCE AND NANOTECHNOLOGY Mahatma Gandhi University

Introduction

A high priority task in the context of education in India is improvement of quality of higher education for equipping young people with skills relevant for global and national standards and enhancing the opportunities for social mobility. Mahatma Gandhi University has initiated an Outcome Based Education (OBE) for enhancing employability of graduates through curriculum reforms based on a learning outcomesbased curriculum framework, upgrading academic resources and learning environment.

Learning outcomes specify what graduates completing a particular Programme of study are expected to know, understand and be able to do at the end of their programme of study. The fundamental premise underlying the learning outcomesbased approach to curriculum development is that higher education qualifications are awarded on the basis of demonstrated achievement of outcomes, expressed in terms of knowledge, understanding, skills, attitudes and values. Outcomes provide the basis for an effective interaction among the various stakeholders. It is the results-oriented thinking and is the opposite of input- based education where the emphasis is on the educational process.

Outcome Based Education (OBE) process

OBE is a comprehensive approach to organize and operate a curriculum that is focused on and defined by the successful demonstrations of learning sought from each learner. The term clearly means focusing and organising everything in an education system around "what is essential for all learners to be able to do successfully at the end of their learning experiences". OBE is an approach to education in which decisions about the curriculum and instruction are driven by the exit learning outcomes that the students should display at the end of a programme or a course. By the end of educational experience, each student should have achieved the outcomes.

Benefits of OBE

The OBE Framework is a paradigm shift from traditional education system into OBE system where there is greater focus on programme and course outcomes. It guarantees that curriculum, teaching and learning strategies and assessment tools are continuously enhanced through a continuous improvement process. All decisions including those related to curriculum, delivery of instruction and assessment are based on the best way to achieve the pre-determined outcomes. Traditionally, educators have measured learning in terms of standardized tests. In contrast, outcome-based education defines learning as what students can demonstrate that they know.

Benefits of OBE:

- More directed & coherent curriculum.
- Graduates will be more "relevant" to industry & other stakeholders (more well- rounded Graduates)
- Continuous Quality Improvement is in place.
- OBE shifts from measuring input and process to include measuring the output (outcome)

Learning Outcomes based Curriculum Framework (LOCF) for Post Graduate Programmes: IQAC MG University

One of the main objectives of OBE is to ensure continuous improvement of programmes in terms of maintaining the relevance in curriculum as well as responding to the requirements of the stakeholders. an OBE system has been proposed and to be implemented at various Departments of Mahatma Gandhi University from 2020-21 academic year onwards, as a quality-assurance approach to improve teaching and learning outcomes and processes. This OBE plan incorporates the "outcomes assessment" process to be followed in the departments. OBE should be a key driver of the curriculum management in all the departments of the university. Therefore, as envisaged by the IQAC of Mahatma Gandhi university, an OBE based curricular framework has been proposed for the Masters programmes of School of Nanoscience and Nanotechnology w.e.f. the academic year 2022- 2023 which is presented hereafter. In this regard, we have framed the syllabus in accordance with the programme outcomes of Mahatma Gandhi University listed below.

Programme Outcomes (PO) of Mahatma Gandhi University

PO 1: Critical Thinking and Analytical Reasoning Capability to analyse, evaluate and interpret evidence, arguments, claims, beliefs on the basis of empirical evidence; reflect relevant implications to the reality; formulate logical arguments; critically evaluate practices, policies and theories to develop knowledge and understanding; able to envisage the reflective thought to the implication on the society.

PO 2: Scientific Reasoning and Problem-Solving Ability to analyse, discuss, interpret and draw conclusions from quantitative/qualitative data and experimental evidences; and critically evaluate ideas, evidence and experiences from an unprejudiced and reasoned perspective; capacity to extrapolate from what one has learned and apply their competencies to solve problems and contextualise into research and apply one's learning to real life situations.

PO 3: Multidisciplinary/Interdisciplinary/Transdisciplinary Approach Acquire interdisciplinary/multidisciplinary/transdisciplinary knowledge base as a consequence of the learning they engage with their programme of study; develop a collaborative-multidisciplinary/interdisciplinary/transdisciplinary-approach for formulate constructive arguments and rational analysis for achieving common goals and objectives.

PO 4: Communication Skills Ability to reflect and express thoughts and ideas effectively in verbal and nonverbal way; Communicate with others using appropriate channel; confidently share one's views and express herself/himself; demonstrate the ability to listen carefully, read and write analytically, and present complex information in a clear and concise manner and articulate in a specific context of communication.

PO 5: Leadership Skills Ability to work effectively and lead respectfully with diverse teams; setting direction, formulating a goal, building a team who can help achieve the goal, motivating and inspiring team members to engage with that goal, and using management skills to guide people to the right destination, in a smooth and efficient way.

PO 6: Social Consciousness and Responsibility Ability to contemplate of the impact of research findings on conventional practices, and a clear understanding of responsibility towards societal needs and reaching the targets for 12 attaining inclusive and sustainable development.

PO 7: Equity, Inclusiveness and Sustainability Appreciate equity, inclusiveness and diversity; acquire ethical and moral reasoning and values of unity, secularism and national integration to enable to act as dignified citizens; able to understand and appreciate diversity, managing diversity and use of an inclusive approach to the extent possible.

PO 8: Moral and Ethical Reasoning Ability to embrace moral/ethical values in conducting one's life, formulate a position/argument about an ethical issue from multiple perspectives, and use ethical practices in all work. Capable of demonstrating the ability to identify ethical issues related to one's work and living as a dignified person in the society.

PO 9: Networking and Collaboration Acquire skills to be able to collaborate and network with scholars in an educational institution, professional organizations, research organizations and individuals in India and abroad.

PO 10: Lifelong Learning Ability to acquire knowledge and skills, including "learning how to learn", that are necessary for participating in learning activities throughout life, through self-paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of work place through knowledge/skill development/reskilling.

Eligibility for Admission

The basic requirement for admission to the M. Sc. Programs will be:

1. B. Sc in Chemistry with Physics and Mathematics as subsidiaries with not less than 60% marks for Part III. In the case of credit and semester pattern, the eligibility shall be corresponding grades. Eligibility criteria/relaxation for the reserved candidates would be as per University/ Government rules.

2. Candidates belonging to Socially and Educationally backward classes (SEBC) referred to GO(P)208/66Edn dated 2-5-96 and subsequent amendments to the order issued by the Government shall be given a relaxation of 2% marks in the prescribed minimum for the admission.

3. A relaxation of 5% marks from the prescribed minimum shall be allowed in the case of physically handicapped persons.

4. Candidates who have passed the qualifying examination in more than one chance in the subject (excluding languages) will have their percentage marks derated at the rate of 5% for every additional appearance for the purpose of ranking.

Admission Procedure

Candidates have to appear for the Common Admission Test (CAT) conducted by the MG University in April/ May of every year. The questions will be of objective multiple-choice type. Any other conditions prescribed by MG University from time to time in this regard will be applicable. Relaxation of marks and Reservation of seats under SC/ST are based on University/ Government Rules. Admission may be based on the written test alone or written test and interview or on the basis of the marks obtained in the qualifying examinations as well as the marks obtained in the written test, the interview and/or the group discussion conducted by the respective Schools as decided by the Faculty Council of Schools/Centres/Institutes from time to time. The Rank list for admission will be prepared as per university guidelines. While preparing the rank list, if there is same index marks for more than one candidate, they will be ranked on the basis of actual marks obtained in the qualifying exam (CAT). Even after this, if there is a tie; they will be ranked on the basis of date of birth that is the older person is to be ranked higher. Each semester shall comprise of a minimum of 18 instructional weeks. Every semester will be adjusted to have at least 90 working days.

Continuous Internal Assessment based evaluation during the course period and End Semester Examination at the end of each semester shall be conducted.

Course Registration

A student must register for the required number of courses as per specific curriculum of a programme, after the commencement of class of that semester. Each student shall have a course card for each semester, wherein the title of the courses and corresponding course codes are entered and signed by the student, the faculty member offering the course and countersigned by the Director/Head of the Department. Based on this, a consolidated statement of courses to which registration is granted for the semester is to be prepared by the department. This statement must be signed by the Director/Head of the department and has to be submitted to the CSS section of the examination branch of the University within 20 days after the commencement of class of each semester.

Duration of the Course

The course shall extend over a period of two academic years consisting of four semesters.

Courses and Credits

Three kinds of courses are offered – Core Courses, Elective Courses and Laboratory courses. Core Courses and Laboratory courses are offered by the School conducting the program. Each course is allotted credits varying from 2 to 4 depending on the hours of instruction / practical. (A 3- credit course, in general, is one which normally involves four hours per week of class room teaching or lecture / seminar/ practical lessons).

Credit Requirements: The minimum total credits required for the successful completion of the M. Sc. program shall be 80.

Course Teaching: Courses shall generally be taught by the faculty who designed the course, though it is possible for the Faculty Council to assign the teaching of a course to more than one faculty.

Internal Assessment: The student's attendance and classroom performance as well as the feedback received from tests, tutorials, assignments and term papers shall form basis for internal assessment. The internal assessment will account for 40% of evaluation. The internal assessment marks shall be distributed as follows and as per regulation in 8 and 10 of CSS regulations 2020 of Mahatma Gandhi University.

A. Theory

Components % of internal marks

1) Two test papers - 60%

2) Assignments/Book Review/debates - 20%

3) Seminars/Presentation of case study - 20%

B. Practical's

Components % of internal marks

1) Two test papers - 40%

2) Lab Skill - 25%

3) Records/Viva - 25%

4) Attendance - 10%

Evaluation

All work pertaining to the Examinations shall be held in the Schools/ Departments of study and research under the direct control and supervision of the Directors/ Heads of the Departments. There shall be continuous internal assessment as well as end semester examinations for all the courses. Evaluation of the courses shall be conducted by the respective faculty members of School of Nanoscience and Nanotechnology. Indirect Grading is employed for the evaluation of courses. The performance of a student in each course is evaluated in terms of percentage of marks converted to grade points.

A candidate will be deemed to have completed the requirements of study of any semester and permitted to appear each University end semester examinations (ESE) only if,

1. The candidate has not less than 75% of attendance in each of the subjects of the total number of working days of the concerned semester.
2. His/her progress has been good
3. His/her character and conduct has been good
4. She/he has minimum of 50 % of sessional marks for each subject.

A student who has an attendance and sessional marks lower than 75% and 50% respectively will not be permitted to appear for the ESE and he/she has to redo the semester at the next available opportunity. However, a candidate can repeat the course or avail condonation of attendance for temporary break of study, only once during entire programme as per existing University rules.

Process of Evaluation

The internal assessment will be a continuous assessment (CA) that accounts for 40% of the evaluation in both theory and practical's. The end semester examination will account for the remaining 60% of the evaluation.

End-Semester Examination: The end semester examination will account for 60% of the evaluation

Continuous Assessment (CA): The student's participation and classroom performance as well as the feedback received from tests, tutorials, assignments and term papers shall form the basis for continuous assessment (CA). It accounts for 40% of the evaluation in both theory and practical's. This assessment shall be based on a predetermined transparent system involving periodic written tests, assignments and seminars in respect of theory courses and based on tests, lab skill, records/viva and attendance in respect of practical courses.

The percentage of marks assigned to various components for internal evaluation is as follows:

a. Theory

Sl. No	Components	% of marks
1.	Test Papers (2)	60
2.	Assignment / Debates/Book review	20
3.	Seminar/ Presentation of Case study	20

b. Practical's

Sl. No	Components	% of internal marks
1.	Lab skill	25

2.	Observation and recording results	40
3.	Punctuality and neatness	10
4.	Viva-voce	25

Test Papers: For each course there shall be at least three class tests during a semester. Average of the marks obtained in the best two tests will be counted as the internal test component of CAS. Valued answer scripts shall be made available to the students for perusal within 10 working days from the date of the tests.

Assignments: Each student shall be required to do 2 assignments for each course. Assignments after valuation must be returned to the students. The teacher shall define the expected quality of the above in terms of structure, content, presentation and the like, and inform the same to the students. Punctuality in submission of assignments/records is to be given a weightage in the internal evaluation.

Seminar: Every student shall deliver one seminar as an internal component of every course and must be evaluated by the respective course teacher in terms of structure, content, presentation and interaction. The soft and hard copies of the seminar report are to be submitted to the teacher in charge.

Results of Continuous Assessment: The results of the CA counter-signed by Head of the school/Centre shall be displayed on the notice board 5 days before the end semester examinations. The marks awarded for various components of the CA shall not be rounded off, if it has a decimal part. The total marks of the CA shall be rounded off to the nearest whole number. Relevant records of continuous assessment (CA) must be kept in the department and that must be made available for verification.

Project Work: There shall be a project to be undertaken by all students. The dissertation entails field work, lab work, report writing, presentation and viva voce. The class hours allotted for project work may be clustered into a single slot so that students can do their work at parent school or other institution for a continuous period of time. However, appropriate changes can be made by the faculty council in this regard. Project/dissertation shall be carried out under the supervision of a teacher in the parent School/Centre/Institute or other research institutes or industrial establishment or university departments if they permit the students to do so, after getting permission from the Department Head. In such cases, one of the teachers from

the schools/centres/institutes would be the co-supervisor/internal guide and an expert from the industry/ research organization concerned shall act as supervisor/ external guide.

In addition to dissertation work, a mini project work should be conducted at the school under the guidance of respective faculties. Students should submit a mini project report and evaluated the same by respective faculties.

Process of evaluation of project work in the fourth semester: The evaluation of the project in the fourth semester will be done by external examiner, based on the work done by the student, content, presentation of the project work and a viva voce. A panel of External Examiners is prepared based on recommendation of Faculty Council of SNNT and approval of the same by Vice Chancellor.

There is no provision for improving the continuous assessment/ final evaluation of the project.

Pattern of Question papers for the End- Semester Written Examination

The question papers set for the end-semester written examination will have three sections and carry 60 marks as detailed below:

Section A – Fourteen short answer questions, minimum one from each Unit. Students will have to answer any ten. Each question will carry two marks (Total 20 marks).

Section B – Seven short essay questions, minimum one from each Unit. Students will have to answer any four. Each question will carry 5 marks (Total 20 marks).

Both sections will contain questions covering all the cognitive levels Remembering/ Understanding/Applying/Analysing/ Evaluating and Creating.

Section C - There will be questions of higher levels of learning for at least 10 marks.
Students needs to answer any 2 out of 4 questions covering all the cognitive levels.
Minimum one question from each module.

The End Semester Examination (ESE) will be of three hours duration and carry 60 marks. The ESE for the core and elective courses shall be conducted based on the following pattern of question paper.

Section	Cognitive level	Choice and Marks of questions	Question specification	Total Marks	Alignment with Course outcomes (COs)
Section A	Remembering/ Understanding/ Applying/Evaluating.	10 out of 14 questions; 2 marks each	Minimum one Question from each unit.	20	Aligned with COs
Section B	Applying/Analysing/ Evaluating/Creating	4 out of 7 questions; 5 marks each	Minimum one Question from each unit	20	Aligned with Cos
Section C	Applying/ Creating/Evaluating/ critical thinking	2 out of 4 questions: 10 marks each.	Minimum one Question from each module.	20	Aligned with Cos

The cognitive levels of questions in the End Semester Examinations are summarised as:

- **Lower levels** of learning (Remembering/Understanding/Applying) :30 to 40%
- **Higher Levels** of Learning (Analyzing/Evaluating/Creating) : 60 to 70%

The **difficulty levels** of questions in the End Semester Examinations are categorised as Low, Medium and High. The percentage of questions in each level of difficulty are given below:

- Low: 20 to 30%
- Moderate: 55 to 65%
- High: 15 to 25%

Grading System

The performance of a student in each course is evaluated in terms of percentage of 21 marks with a provision for conversion to grade points. The grading system followed is that of relative grading on a ten-point scale. The following table indicates the performance range and the relative value of the grades (grade points) on the scale.

Performance range and the Relative value of the Grades (Grade points)

Range of % of marks	Letter Grade	Performance	Grade points
95 to ≤ 100	O	Outstanding	10
85 to ≤ 95	A PLUS	Excellent	9
75 to ≤ 85	A ONLY	Very Good	8
65 to ≤ 75	B PLUS	Good	7
55 to ≤ 65	B ONLY	Above Average	6
45 to ≤ 55	C	Average	5
40 to ≤ 45	P	Pass	4
< 40	F	Fail	0
Absent	Ab	Absent	0

Minimum grade for passing in a course or programme: The minimum for a pass in a course is 'P' grade. The minimum credit point requirement (CGPA) for the programme is four.

Consolidation and Declaration of Results and Issue of Grade Cards

All work pertaining to the Examinations shall be held in the Schools/ Departments of study and research under the direct control and supervision of the Directors/ Heads of the Departments. The Director of each School will, in consultation with the Faculty Council, nominate a senior teacher as the Chief Examiner who will help him/her in the matter. The marks awarded for internal assessment will be displayed in the School's notice board at the end of each semester. The Pass Board will consist entirely of the faculty of the Centre and will be constituted by the director on the advice of the Faculty Council. The tabulated Grade sheets will be forwarded after each end – semester examination to the office of the Controller of the

Examinations. The CSS section in the Controller's office will check the Grade Card for any errors and notify the results after consolidating them. On completion of the final semester, a consolidated Grade Card showing the details of all the courses taken during the programme will be issued to the students. The consolidated Grade Card will contain the details of all the courses with their titles, credits, grades obtained, the total credits earned, the SGPA and the CGPA.

Revaluation

The answer scripts of examinations under CSS shall have provisions for revaluation. Evaluation or Scrutiny of answer scripts for the first and third semester is provided. There is no provision for revaluation or scrutiny of answer scripts for the End Semester Examinations of 2nd and 4th Semesters as double valuation is performed on the scripts. The application for scrutiny and revaluation of answer scripts shall be submitted to the Head of the concerned School/ Department/ Centre within 15 days from the date of publication of the results.

Reappearance and improvement in Examinations:

A student who failed for a course in a semester can register for Reappearance in the forthcoming examination, subject to the conditions set forth in these regulations. Improvement of marks/grades in the forthcoming examination can be done, subject to the conditions set forth in these regulations.

Registration for Improvement

A candidate has to apply for registration for improvement by paying the requisite fee. Candidates are not permitted to register for improvement of grades for Individual course. Candidates in the 1st and 2nd semesters, who have secured SGPA letter grade 'P' or above in the End Semester Examination can improve their grade by reappearing for all the semester courses along with the next immediate batch. In such cases a candidate will be awarded a new grade only if there is an improvement in grade in the new examination; otherwise, the candidate is eligible to retain the grade already awarded. Candidates in the 3rd semester, who have secured the SGPA letter grade 'P' or above in the End Semester Examination, can improve their grade by reappearing for all the semester courses, along with the 3rd semester supplementary examination being conducted for failed candidates immediately after the completion of End Semester Examination of Fourth semester. This provision is applicable only for third semester. Improvement of the 4th semester can be done along with the immediate lower batch. If the improvement is meant to obtain minimum CGPA requirement, a candidate has the option to decide which semester (3rd or 4th) is to be improved; however, the grade given to the candidate shall be that obtained for the entire semester improvement examination. 1st and 2nd semester SGPA cannot be improved after the completion of the 4th semester. Only 3rd and 4thsemester SGPA can be improved after the completion of a programme.

The marks/grades awarded for Continuous assessment and that for the Project/dissertation cannot be improved. SGPA secured in the 4thsemester can be improved only for the purpose of fulfilling the minimum CGPA requirement.

Reappearance

Candidates in the 1st and 2nd semesters who have secured a letter grade of 'F' or 'Ab' in any of the courses can avail two immediate consecutive chances to reappear for 23 examination, course wise, provided the candidate has applied for the same and paid the required fee. Candidate in the 3rd semester who has secured letter grade of 'F' or 'Ab' in any of the courses can reappear for exams course-wise in the 3rd semester supplementary examination, which will be conducted immediately after the completion of End Semester Examination of Fourth semester, provided the candidate has applied for the same and paid the required fee (fee for supplementary examination of any course shall be full semester examination fee irrespective of number of courses involved). Candidates who secured the grade of only 'F' or 'Ab' in a course in the 4th semester examination can re-appear course wise, along with the immediate lower batch. Candidates who secured the grade of only 'F' or 'Ab' in a course in the 3rd /4th semester examinations will be given two additional chances for course-wise reappearance even after the completion of the programme; but it has to be done within a period of two years after the completion. In such cases a candidate has to apply for the same as a supplementary exam and pay the required fee (Fee for supplementary examination of any course shall be full semester examination fee irrespective of number of courses involved).

REQUIREMENTS OF ATTENDANCE AND PROGRESS

A candidate will be deemed to have completed the requirements of study of any semester and permitted to appear each University end semester examinations
(ESE) only if,

1. The candidate has not less than 75% of attendance in each of the subjects of the total number of working days of the concerned semester.
2. His/her progress has been good
3. His/her character and conduct has been good
4. She/he has minimum of 50 % of sessional marks for each subject. A student who has an attendance and sessional marks lower than 75% and 50% respectively will not be permitted

to appear for the ESE and he/she has to redo the semester at the next available opportunity. However, a candidate can repeat the course or avail condonation of attendance for temporary break of study, only once during entire programme as per existing University rules.

PROCEDURE FOR COMPLETING COURSE

The academic year will be divided into four semesters, the odd semester normally commencing at the beginning of the academic year and even semester ending with the academic year. A candidate can proceed to the course of study of any semester (other than first semester) if and only if he has completed the course in the previous semester and has registered for the examination of the previous semester. A candidate who is required to repeat the course of any semester for want of attendance / progress or who desires to re-join the semester after a period of discontinuance or who upon his own request is specially permitted to repeat the semester in order to improve his performance, may join the semester for which he is eligible or permitted to join. On discontinuation of the course, the student should refund the entire stipend he/she received from the University within one year. The transfer certificate and other certificates will be issued only after refunding the stipend.

ADD-ON COURSES

In addition to Core, elective and practical courses the school will offer add-on courses such as; Nano catalysis, Social, ethical and legal issues of Nanoscience and Nanotechnology, Nano sensors, Advanced nanobiology, Waste management, and Water purification through Nanoscience and Nanotechnology. The course structure and syllabus will be announced before commencement of each semesters. The lectures will be delivered by reputed Professors/ Scientists from other Universities/ Institutions in India or Abroad.

Faculty

Upon successful completion of two years in the program the candidates will be awarded a Master's Degree under the Faculty of Science.

(As per the M G university CSS regulations amended from time to time.

Scheme and Syllabi

Programme:

M.Sc. Chemistry (Nanoscience and Nanotechnology)

MAHATMA GANDHI UNIVERSITY

SCHOOL OF NANOSCIENCE AND NANOTECHNOLOGY

PROGRAMME : M.Sc. Chemistry (Nanoscience and Nanotechnology)

DURATION : 2 years (2021 Admission onwards)

Total credits : 82 (for 4 semesters) [Core: 64; Elective: 14; Open: 4]

**The student has to choose three elective courses for semester I, two elective courses for semester II and two elective courses for semester III.

**The student has to choose one open course of 4 credits for semester III from any other School under the Faculty of Science.

*** In the evaluation process internal –Continuous Assessment (CA) - accounts for 40% and the End-Semester Examination will account for the remaining 60%.

Program Specific Outcomes:(PSOs): At the completion of the M.Sc. Chemistry (Nanoscience and Nanotechnology) programme, the students from school of Nanoscience and Nanotechnology will be able to:

PSO	
1	Provide a strong foundation in Chemistry that emphasizes scientific reasoning and analytical problem solving.
2	Provide students with the skills required to succeed in M.Sc., also enrich the students with a basic skill to perform in Chemical industry especially in the field of Nanoscience and Nanotechnology.
3	Promote research interest in students and enable them towards planning and execution of research in frontier areas of chemical sciences.
4	Expose the students to a level of experimental techniques using modern instrumentation.
5	Demonstrate teamwork, communication, Time management and leadership skills across multicultural contexts.
6	Acquire the ability to synthesize and characterize compounds using sophisticated instrumental techniques and related soft-wares, for the indepth characterization of nano materials

7	Develop solid knowledge, understanding and expertise in the domain of Nanoscience and Nanotechnology.

SEMESTER I (21 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
Core Courses						15
NSM21C59	**Theoretical Chemistry I- Quantum Mechanics and Group Theory**	2	2	-	3	
NSM21C60	**Inorganic chemistry I-Chemistry of Main Group Elements, Lanthanides and actinides**	2	2	-	3	
NSM21C61	**Structural and Molecular Organic Chemistry, Stereo chemistry of Organic compounds, Aromaticity**	2	2	-	3	
NSM21C62	**Co-ordination Chemistry**	3	2	-	3	
NSM21C63	**Practical I - Inorganic Chemistry**	-	-	6	3	
***Elective Courses (Choose any three)**						6
NSM21E46	**Chemistry of natural products**	2	-	-	2	
NSM21E47	**Spectroscopic methods in chemistry**	2			2	
NSM21E48	**Polymer Chemistry**	2	-	-	2	
NSM21E49	**Chemical Kinetics**	2			2	
NSM21E50	**Analytical chemistry**	2			2	
NSM21E51	**Chemical Thermodynamics**	2			2	

SEMESTER II (22 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
Core Courses						18
NSM21C64	**Statistical thermodynamics**	3	2	-	3	
NSM21C65	**Organometallic chemistry, Bio inorganic chemistry**	2	2	-	3	
NSM21C66	**Nuclear chemistry: nuclear reactions, fission and fusion, radio-analytical techniques and activation analysis**	2	2	-	3	
NSM21C67	**Organic Chemistry I-Reaction Mechanisms, Named reactions and common organic reagents**	2	2	-	3	
NSM21C68	**Quantum Mechanics and Applications**	2	2	-	3	
NSM21C69	**Organic Chemistry Lab -I**	-	-	6	3	

*Elective Courses (Choose any two)						
NSM21E52	**Introductions to Nanomaterials**	2	-	-	2	4
NSM21E53	**Design, synthesis and fabrication of nanomaterials**	2	-	-	2	
NSM21E54	**Drug design and Medicinal chemistry**	2	-	-	2	

SEMESTER III (23 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
Core Courses						15
NSM21C70	**Physical Chemistry**	2	2	-	3	
NSM21C71	**Advanced Characterization techniques for Nanomaterials**	2	2	-	3	
NSM21C72	**Organic Chemistry II – Advanced Organic Chemistry**	3	2	-	3	
NSM21C73	**Practical III-Physical Chemistry Lab-I**	-	-	6	3	
NSM21C74	**Practical IV – Synthesis and Characterization of Nanomaterials**	-	-	6	3	
***Elective Courses (Choose any two)**						4
NSM21E55	**Nanotechnology in Energy**	2	-	-	2	
NSM21E56	**Advanced Nanobiology**	2	-	-	2	
NSM21E57	**Mathematical and Computational Chemistry**	2	-	-	2	
****Open Course**						4
	Open Course	4	-	-	4	

SEMESTER IV (16 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
Core Courses						16
NSM21C75	**Dissertation and Viva-voce**	-	-	-	10	
NSM21C76	**Industrial visit/ Review**				3	
NSM21C77	**Mini Project**				3	
****Open Courses offered by School of Nanoscience and Nanotechnology**						

NSM21O-01	**Nanoscience and Nanotechnology**	4	-	-	4	

SEMESTER 1

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SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Theoretical Chemistry I- Quantum Mechanics and Group Theory**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C59**

Course Summary & Justification	This course aims to equip students with symmetry elements and symmetry operations and will be able to determine the point groups of molecules and ions. This course offers the students to determine symmetry in crystals. A detailed mathematical groups, group multiplication tables, and matrix representation of elements. Introduces reducible and irreducible representations and application in					
	chemical bonding and SALCs of C2v, C3v, D3h and C2h molecules					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, collaborative learning, independent learning	40	40	0	40	120
Pre-requisite	Basic knowledge about quantum mechanics and group theory					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome Upon completion of this course, students will be able to;	Learning Domains	PSO No.
1	Explain the Symmetry elements and symmetry operations, and determine the point groups of molecules and ions	U	1,2
2	Understand symmetry in crystals and crystallographic point groups	U,A	1-6
3	Gather information about mathematical groups and group multiplication tables	U,R	3,4
4	To study reducible and irreducible representations and application in chemical bonding	U	1-4
5	Understand construction of symmetry adapted linear combination of atomic orbitals	U,A	1,2,5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	**Group Theory and Applications in Chemical Bonding (36 Hrs)** **Symmetry elements and symmetry operations**, Determination of point groups of molecules and ions (organic / inorganic / complex) belonging to Cn, Cs, Ci, Cnv, Cnh, C∞v, Dnh, D∞h, Dnd, Td and Oh point groups.	**15**	**1,2**
Module 2	**Symmetry in crystals**, crystallographic point groups (no derivation), Hermann Mauguin symbols, Screw axis-pitch and fold of screw axis, glide planes, space groups (elementary idea only).	**15**	**1,3**
Module 3	**Mathematical groups**: Properties, Abelian groups, cyclic groups, sub groups, similarity transformation, classes - C2v, C3v and C2h, Group multiplication tables (GMTs) - C2v, C3v and C2h, isomorphic groups, Matrix representation of elements like E, Cn, Sn, I, σ-matrix representation of point groups like C2v, C3v, C2h, C4v - trace /character, block factored matrices.	**15**	**4**

Module 4	**Reducible and irreducible representations**, standard reduction formula, statement of great orthogonality theorem (GOT), construction of character tables for C2v, C2h, C3v and C4v, Application in chemical bonding: Projection operator, transformation properties of atomic orbitals, construction of symmetry adapted linear combination of atomic orbitals (SALCs) of C2v, C3v, D3h and C2h molecules.	**15**	**5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ○ Surprise test ○ Internal Test – Objective and descriptive answer type ○ Submitting assignments ○ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

References:

1. F. A. Cotton, ChemicalApplicationsof Group Theory, 3rdEdn., Wiley Eastern, 1990
2. L. H. Hall, Group Theory and Symmetry in Chemistry, McGraw Hill,1969
3. V. Ramakrishnan, M.S.Gopinathan, Group Theory in Chemistry, Vishal Publications, 1992
4. S. Swarnalakshmi, T. Saroja, R.M.Ezhilarasi, A Simple Approach to Group Theory in Chemistry, Universities Press, 2008
5. S.F.A. Kettle, Symmetry and Structure: Readable Group Theory for Chemists, 3rd Edn. , Wiley, 2007.
6. A.Vincent, Molecular Symmetry and Group Theory: A Programmed Introduction to Chemical Applications, 2nd Edn. , Wiley, 2000
7. A. S. Kunju, G. Krishnan, Group Theory and its Applications in Chemistry, PHI Learning, 2010
8. K.VeeraReddy,Symmetry and Spectroscopy of molecules,New Age International (P) Ltd,1999

	MAHATMA GANDHI UNIVERSITY
SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Inorganic chemistry I-Chemistry of Main Group Elements, Lanthanides and actinides**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C60**

Course Summary & Justification	The study of Main Group Chemistry unravels the basic composition, structures, and bonding. Through this learning, it is possible to acquire relevant conceptual and procedural knowledgeto develop understanding and appreciation of developments in various scientific and technological fields. The course also aims to help the students to understandboron hydrides, structure and bonding in phosphorous-sulphur and sulphurnitrogen compounds.This course aims to impart basic knowledge on the synthesis, structure and bonding of cage like structures andclusters. Cages and clusters of tellurium, Mercuride clusters in amalgams will be discussed. The applications of clusters, DNA binders etc.will also be described at the conclusion part to understand importance of learning this course.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, collaborative learning, independent learning	40	40	0	40	120
Pre-requisite	Basic knowledge about Main Group Elements (undergraduate level)					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome Upon completion of this course, students will be able to;	Learning Domains	PSO No.
1	Understand the synthesis, structure and bonding, Inorganic Chains and Rings, catenation, hetero catenation	U	1,2
2	To study the synthesis, structure and applications of Zeolites, isopolyand heteropoly acidsof molybdenum and tungsten and one dimensional conductors	U,A	2,3,4,8
3	Understand the topological approach to boron hydrides, STYX number in rationalizing the structure of main group clusters	U,R	1,2,3
4	To have a thorough knowledge of structure and bonding in Heterocyclic inorganic ring systems- phosphorous-sulphur and sulphur-nitrogen compounds	U	2,3,4
5	To learn the structure and bonding in homocyclic inorganic ring systems- sulphur, selenium and phosphorous compounds	U,A	2,3
6	To understand the synthesis, structure and bonding of cages and clusters of various inorganic elements	U, R	1,2,3,4
7	Gain knowledge about the medical applications of boron clusters- nucleic acid precursors, DNA binders, and application of C2B10 for Drug Design	U,A	4,5,8
8	To learn about Transition elements and Inner transition Elements: spectral and magnetic properties	U,R	3,4,5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	**Main group elements and their compounds**: Allotropy, synthesis, structure and bonding, Inorganic Chains and Rings: Chains: Catenation, hetero catenation, silicones, Zeolites: Synthesis, structure and applications, isopoly acids of vanadium, molybdenum and tungsten, heteropoly acids of Mo and W, polythiazil-one dimensional conductors.	**15**	**1,2**
Module 2	Infinite metal chains, Rings, topological approach to boron hydrides, styx numbers, Heterocyclic inorganic ring systems: Structure and bonding in phosphorous-sulphur and sulphur-nitrogen compounds,Homocyclic inorganic ring systems: Structure and bonding in sulphur, selenium and phosphorous compounds.	**15**	**3,4,5**
Module 3	**Inorganic Cages and Clusters**: Synthesis, structure and bonding of cage like structures of phosphorous, Boron cage Aluminium, indium and gallium clusters, cages and clusters of germanium, tin and lead, cages and clusters of tellurium, Mercuride clusters in amalgams, Medical applications of boron clusters- nucleic acid precursors, DNA binders, application of C2B10 for Drug Design, Nuclear receptor ligands bearing C2B10cagesustrial importance of the compounds.	**15**	**6,7**
Module 4	**Transition elements** and **Inner transition Elements*:*** spectral and magnetic properties.	**15**	**8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student

Assessment Types	Mode of Assessment C. **Continuous Internal Assessment (CIA)** ○ Surprise test ○ Internal Test – Objective and descriptive answer type ○ Submitting assignments ○ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar D. **Semester End examination**

References:

1. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry: A Comprehensive Text, 3 rdEdn.,Interscience,1972
2. J.E.Huheey, E. A.Keiter, R.A.Keiter, Inorganic Chemistry Principles of Structure and Reactivity, 4thEdn. , Pearson Education India, 2006
3. K.F. Purcell, J.C.Kotz, Inorganic Chemistry, Holt-Saunders, 1977
4. F. Basolo, R.G. Pearson, Mechanisms of Inorganic Reaction, John Wiley & Sons, 2006
5. B. E. Douglas, D.H. McDaniel, J.J.Alexander, Concepts and Models of Inorganic Chemistry, 3rdEdn., Wiley-India, 2007
6. R.S. Drago, Physical Methods in Chemistry, Saunders College, 1992
7. B. N. Figgis, M. A.Hitchman, Ligand Field Theory and its Applications, Wiley-India, 2010
8. J.D. Lee, Concise Inorganic Chemistry, 4thEdn. , Wiley-India, 2008
9. R. G. Wilkins, Kinetics and Mechanisms of Reactions of Transition Metal Complexes, Wiley VCH, 2002
10. G. A.Lawrance, Introduction to Coordination Chemistry, John Wiley & Sons Ltd, 2010
11. C. E.Housecroft, A. G. Sharpe, Inorganic Chemistry, Pearson, 2012

MAHATMA GANDHI UNIVERSITY

	School of Nanoscience and Nanotechnology
Programme	**M.Sc.**
Course Name	**Structural and Molecular Organic Chemistry, Stereo chemistry of Organic compounds, Aromaticity**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C61**

Course Summary & Justification	The course is designed to address the fundamental concepts and mechanisms of organic chemistry reactions, basic organic reaction mechanisms,Physical Organic Chemistry, stereochemistry and conformational analysis of organic compounds. Through this learning, the students will be able to describe the chemical and molecular processes that take place in organic chemical reactions, and to differentiate various types of nucleophilic substitution and elimination reactions. They are suggested to understand the basic concepts and various types of aromaticity, kinetic versus thermodynamic control of product formation, Linear free energy relationships-Hammet equation, Taft equation and also a good knowledge of stereochemical aspects of organic reactions. A good understanding of types of isomerism and stereochemical notations are also advisable. This course would help the students to grasp the aforementioned domains with thorough learning and practice.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, collaborative learning, independent learning	40	40	0	40	120
Pre-requisite	Fundamentals of organic chemistry and stereochemical notations					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome Upon completion of this course, students will be able to;	Learning Domains	PSO No.
1	To revise and understand basic concepts of aromaticity and electron displacement effects	R, U	1,2
2	To illustrate the reaction mechanism aspects in the context of elimination and substitution reactions	U, An, E	2,3
3	To predict the mechanisms of different organic reactions	An, A, S	1,2,3

4	To learn the kinetic and thermodynamic control of product formation and linear free energy relationships	U	1,4,6
5	To understand the catalysis by acids, bases and nucleophiles in various organic reactions and mechanisms	U,A	2,3,4,5
6	To have a thorough knowledge of Hard and soft acids, bases - HSAB principle and its applications	U,R	2,3,4
7	Gain knowledge about stereoisomerism and a detailed study on chirality of organic molecules	U,R,A	4,5,6
	using units such as center, axial, planar, and helicity.		
8	To have a thorough knowledge of geometrical isomerism nomenclature, E-Z notation, methods of determination and its interconversion	U,A	5,6,8
9	To learn the factors affecting conformational stability of molecules, and conformational analysis of organic molecules	U,R,A	2,3,4
10	To understand the conformation and reactivity of elimination and chemical consequence of conformational equilibrium	U,A	1,2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	**Review of basic concepts in organic chemistry:**Bonding, hybridization, MO picture of butadiene and allyl systems, Electron displacement effects: Inductive effect, electrometric effect, resonance effect, hyperconjugation, steric effect, Bonding weaker than covalent bonds. **Concept of aromaticity**: Delocalization of electrons - Hückel's rule, criteria for aromaticity, examples of neutral and charged aromatic systems - annulenes, NMR as a tool, carbon nanotubes and graphene	**15**	**1-4**

	Mechanism of electrophilic and nucleophilic aromatic substitution reactions with examples,Arenium ion intermediates, SN1, SNAr, SRN1 and benzyne mechanisms.		
Module 2	**Physical Organic Chemistry** Energy profiles, Kinetic versus thermodynamic control of product formation, Hammond postulate, kinetic isotope effects with examples, Linear free energy relationships-Hammet equation, Taft equation. Catalysis by acids, bases and nucleophiles with examples from acetal, cyanohydrin, Ester formation and hydrolysis reactions of esters- AAC2, AAC1, AAL1, BAC2and BAL1 mechanisms, Hard and soft acids, bases - HSAB principle and its applications (organic reactions only)	**15**	**5,6**

Module 3	**Stereochemistry of Organic Compounds:** Stereoisomerism: Definition based on symmetry and energy criteria, configuration and conformational stereoisomers, **Centre of chirality:** Molecules with C, N, S based chiral centres, absolute configuration, enantiomers, racemic modifications, R and S nomenclature using Cahn-Ingold-Prelog rules, molecules with a chiral centre and Cn, molecules with more than one centre of chirality, definition of diastereoisomers, constitutionally symmetrical and unsymmetrical chiral molecules, erythro and threo nomenclature. Axial, planar and helical chirality with examples, stereochemistry and absolute configuration of allenes, biphenyls and binaphthyls, ansa and cyclophanic compounds, spiranes, exo-cyclic alkylidene cycloalkanes,Topicity and prostereo isomerism, topicity of ligands and faces as well as their nomenclature, NMR distinction of enantiotopic/diastereotopic ligands.	**15**	**7,8**
Module 4	**Geometrical isomerism:** nomenclature, E-Z notation, methods of determination of geometrical isomers, interconversion of geometrical isomers. **Conformational Analysis:** Conformational descriptors: Factors affecting conformational stability of molecules, conformational analysis of substituted ethanes, cyclohexane and its derivatives, decalins, adamantane, norbornane, sucrose and lactose, Conformation and reactivity of elimination (dehalogenation,dehydrohalogenation, semipinacolic deamination and pyrolytic elimination - Saytzeff and Hofmann eliminations),	**15**	**8,9,10**

	substitution and oxidation of 2o alcohols, Chemical consequence of conformational equilibrium - Curtin Hammett principle.		

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **E.Continuous Internal Assessment (CIA)** • Surprise test • Internal Test – Objective and descriptive answer type • Submitting assignments • Seminar Presentation – select a topic of choice in the concerned
	area and present in the seminar **F.Semester End examination**

References:

1. R. Bruckner, Advanced Organic Chemistry: Reaction Mechanisms, Academic Press, 2002
2. F. A. Carey, R.A. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, 5thEdn., Springer, 2007
3. J.Clayden, N. Greeves, S. Warren, P.Wothers, Organic Chemistry, Oxford University Press, 2004
4. T.H. Lowry, K. S. Richardson, Mechanism and Theory in Organic Chemistry, 2 ndEdn., Harper & Row, 1981
5. N. S. Isaacs, Physical Organic Chemistry, ELBS/Longman, 1987
6. D.Nasipuri, Stereochemistry of Organic Compounds: Principles and Applications, 3rdEdn. , New Age Pub., 2010
7. D. G. Morris, Stereochemistry, RSC, 2001
8. E. L. Eliel, S. H. Wilen, Stereochemistry of Organic Compounds, John Wiley & Sons, 1994
9. N. J. Turro, V. Ramamurthy, J. C.Scaiano, Principles of Molecular Photochemistry: An Introduction, University Science books, 2009

10. N. J. Turro, Modern Molecular Photochemistry, Benjamin Cummings, 1978
11. K. K. R. Mukherjee, Fundamentals of Photochemistry, New Age Pub., 1978

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SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Co-ordination Chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C62**

Course Summary & Justification	The course aims to help the students to detail out the classification of complexes structures and properties of coordination complexes. The description of various bonding theories with emphasizes on the spectral and magnetic properties of coordination complexes helps to predict the characteristic properties of any transition metal complex. Different reactions in transition metal complex with a supportive mechanism will be discussed.Through this learning, it is possible to acquire well knowledge about magnetic properties of complexes and temperature dependence of magnetism. This course offers thermodynamic and kinetic stability of metal complexes, mechanism of octahedral substitution, replacement and electron transfer reactions. Term symbols for lanthanide ions, its electronic spectra and magnetic properties, organometallic complexes of the lanthanoids, general characteristics of actinoids and electronic spectra and magnetic properties of lanthanoids and actinoids are discussed atthe end of this course					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours

	Authentic learning, collaborative learning, independent learning	40	40	0	40	120
Pre-requisite	Basic knowledge about periodic table and arrangements of elements under Groups and Periods. Basic knowledge in Inorganic Chemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome Upon completion of this course, students will be able to;	Learning Domains	PSO No.
1	Able to understand classification and stability of complexes	U	1,2
2	To understand the splitting of d orbitals in different fields and various theories of coordination complexes	U,A	1,2,3
3	To study the Term symbols of dn system, correlation diagrams for d1 and d9 ions in octahedral and tetrahedral fields	U,R	1,2,3
4	Should be able to interpret electronic spectra of complexes, charge transfer spectra, and luminescence spectra	U	4,5,6
5	To evaluate the magnetic properties of complexes, temperature dependence of magnetism, temperature independent paramagnetism and anomalous magnetic moments	U,A	3,4,5
6	Should be able to understand thermodynamic and kinetic stability of metal complexes, kinetics and mechanism of octahedral substitution	U, R	5,6
7	To understand the replacement reactions, electron transfer reactions, two electron transfer and intramolecular electron transfer	U, A	3,4,5
8	Gather information about Term symbols for lanthanide ions, coordination complexes of the lanthanoids and electronic and magnetic properties	U,R	1,2,3

9	General characteristics of actinoids, its coordination complexes and electronic spectra and magnetic properties	U	1,3,4,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	**Structural Aspects and Bonding:** Classification of complexes based on coordination numbers and possible geometries, sigma and pi bonding ligands such as CO, NO, CN^-, R3P, and Ar3P, Stability of complexes, thermodynamic aspects of complex formation-Irving William order of stability, chelate effect. Splitting of d orbitals in octahedral, tetrahedral, square planar, square pyramidal and triagonal bipyramidal fields, LFSE, Dq values, Jahn Teller (JT) effect, theoretical failure of crystal field theory, evidence of covalency in the metal-ligand bond, nephelauxetic effect, ligand field theory, molecular orbital theory- M. O energy level diagrams for octahedral and tetrahedral complexes without and with π-bonding, experimental evidences for pi-bonding	**15**	**1,2,3**

Module 2	**Spectral and Magnetic Properties of Metal Complexes** **Electronic Spectra of complexes:** Term symbols of dn system, Racah parameters, splitting of terms in weak and strong octahedral and tetrahedral fields, correlation diagrams for d1 and d9 ions in octahedral and tetrahedral fields (qualitative approach), d-d transitions, selection rules for electronic transitions-effect of spin orbit coupling and vibronic coupling. **Interpretation of electronic spectra of complexes**: Orgel diagrams and demerits, TanabeSugano diagrams, calculation of Dq, B and β (Nephelauxetic ratio) values, spectra of complexes with lower symmetries, charge transfer spectra, luminescence spectra. **Magnetic properties of complexes**-paramagnetic and diamagnetic complexes, molar susceptibility, Gouy method for the determination of magnetic moment of complexes, spin only magnetic moment, Temperature dependence of magnetism- Curie's law, Curie-Weiss law, temperature independent paramagnetism (TIP), spin state cross over, antiferromagnetism-inter and intra molecular interaction, anomalous magnetic moments.	**15**	**4,5**
Module 3	**Kinetics and Mechanism of Reactions in Metal Complexes** Thermodynamic and kinetic stability, kinetics and mechanism of nucleophilic substitution reactions in square planar complexes- trans effect-theory and applications, effect of entering ligand, effect of leaving group and effect of ligands already present on reaction rate, effect of solvent and reaction pathways, substitution in tetrahedral and fivecoordinate complexes ,Kinetics and mechanism of octahedral substitution- water exchange, dissociative and associative mechanisms, base hydrolysis, racemization reactions, solvolytic reactions (acidic and basic), Replacement reactions involving multidendate ligands- formation of chelates, effect of H+ on the rates of substitution of chelate complexes, metal ion assisted and ligand assisted dechelation, Electron transfer reactions: Outer sphere mechanism-Marcus theory, inner sphere mechanism-Taube mechanism, mixed outer and inner sphere reactions, two electron transfer and intramolecular electron transfer.	**15**	**6,7**
Module 4	**Coordination Chemistry of Lanthanoids and Actinoids:** Term symbols for lanthanide ions,	**15**	**8,9**

	inorganic compounds and coordination complexes of the lanthanoids upto coordination, electronic spectra and magnetic properties of lanthanoid complexes, organometallic complexes of the lanthanoids- σ-bonded complexes, cyclopentadienyl complexes, organo lanthanoid complexes as catalysts, General characteristics of actinoidsdifference between 4f and 5f orbitals, coordination complexes of the actinoids- sandwich complexes, coordination complexes and organometallic compounds of thorium and uranium, comparative account of coordination chemistry of lanthanoids and actinoids with special reference to electronic spectra and magnetic properties.		

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **G. Continuous Internal Assessment (CIA)** • Surprise test • Internal Test – Objective and descriptive answer type • Submitting assignments • Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **H. Semester End examination**

References:

1. F. A. Cotton, G.Wilkinson, Advanced Inorganic Chemistry: A Comprehensive Text, 3rdEdn., Interscience,1972
2. J. E.Huheey, E.A. Keiter, R. A.Keiter, Inorganic Chemistry Principles of Structure and Reactivity, 4thEdn., Pearson Education India, 2006
3. K. F. Purcell, J. C. Kotz, Inorganic Chemistry, Holt-Saunders, 1977
4. F. Basolo, R. G. Pearson, Mechanisms of Inorganic Reaction, John Wiley & Sons, 2006
5. B. E. Douglas, D. H. McDaniel, J. J. Alexander, Concepts and Models of Inorganic Chemistry, 3rdEdn., Wiley-India, 2007
6. R. S. Drago, Physical Methods in Chemistry, Saunders College, 1992

7. B. N. Figgis, M. A.Hitchman, Ligand Field Theory and its Applications, Wiley-India, 2010
8. J. D. Lee, Concise Inorganic Chemistry, 4thEdn., Wiley-India, 2008
9. R. G. Wilkins, Kinetics and Mechanisms of Reactions of Transition Metal Complexes, Wiley VCH, 2002
10. G. A.Lawrance, Introduction to Coordination Chemistry, John Wiley & Sons Ltd, 2010
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MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Inorganic Chemistry Lab 1**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C63**

Course Summary & Justification	The laboratory practical course enables the students to understand and apply the lab skills and laboratory safety procedures needed to carry out standard chemistry experimental techniques. This course will facilitate the students to apply the basic concepts of inorganic chemistry to analyze the metal ions in a given sample. Through this course the students will learn to (i) separate and identify cations in a given mixture (ii) estimate the metal ions using colorimetry (iii) perform complexometric titrations of metal ions with double burette method (iv) separate and estimate binary mixture of metal ions using combined volumetric and colorimetric methods and (v) tabulate and analyze the results of all the experiments systematically. This course will improve the analytical skill and critical thinking including observation, hypothesis development, measurement and data collection, experimentation, evaluation of evidence, and employment of mathematical analysis.
Semester	**I**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, collaborative learning, independent learning			40	40	80
Pre-requisite	The chemistry laboratory is a place of discovery and learning but at the same time it can be a place of danger if proper common-sense of precautions are not taken care. So the students are expected to learn and follow the general safety guidelines to ensure a safe laboratory environment. Also a basic knowledge on inorganic salt analysis, colorimetric estimations and complexometric titrations is preferred.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** **Upon completion of this course, students will be able to;**	**Learning Domains**	**PSO No.**
1	Perform basic chemical lab procedures by following appropriate lab safety measures & Infer the experimental results with mathematical and analytical reasoning.	U,C,I	3,5, 6,7
2	Separation and identification of the mixture of cations in a given sample	A,E, An, S	5,6,7
3	Estimation of the amount of metal ion present in the whole of the given solution colorimetrically	A, An,S	2,3
4	Preparation and characterization complexes using IR, NMR and electronic spectra	U, An, S,I	1,2,7
5	Develop the skills to carry out basic quantitative and qualitative analytical techniques	S,Ap	3,5,8
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**

Module 1	**Separation and identification of a mixture of four cations** A mixture of two familiar ions such as Ag+ , Hg2+, Pb2+, Cu2+, Bi2+, Cd2+, As3+, Sn2+, Sb3+, Fe2+, Fe3+, Al3+, Cr3+, Zn2+ , Mn2+ , Co2+, Ni2+, Ca2+, Sr2+, Ba2+, Mg2+, Li+ , Na+ , K+ and NH4+ and two less familiar metal ions such as Tl, W, Se, Mo, Ce, Th, Ti, Zr, V, U and Li), Anions which need elimination not to be given, Minimum eight mixtures to be given.	**15**	**1,2,5**
Module 2	**Colorimetric estimation** of Fe, Cu, Ni, Mn, Cr, NH4+, nitrate and phosphate ions.	**10**	**1,3,5**
Module 3	**Preparation and characterization complexes using IR, NMR and electronic spectra,** (a) Tris (thiourea)copper(I) complex (b) Potassium tris (oxalate) aluminate (III), (c) Hexammine cobalt (III) chloride, (d) Tetrammine copper (II) sulphate, (e) Schiff base complexes of various divalent metal ions, (f) Bis(dimethylglyoximato) nickel (II) (g) Prussian blue	**15**	**4,5**

TeachingandLearningApproach	**Classroom Procedure (Mode of transaction)** **1.** Direct Instruction: Lecture, Explicit Teaching, E-learning **2.** Interactive Instruction:, Active co-operative learning, Authentic learning
AssessmentTypes	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** oTwo internal tests oLab skill oAttendance oViva voce oLab record **B. Semester End examination**

References:

1. A. I. Vogel, G. Svehla, Vogel's Qualitative Inorganic Analysis, 7thEdn. , Longman,1996

2. A. I. Vogel, A Text Book of Quantitative Inorganic Analysis, Longman, 1966

3. I. M. Koltoff, E. B. Sandell, Text Book of Quantitative Inorganic analysis, 3rdEdn., McMillian, 1968

4. V. V. Ramanujam, Inorganic Semimicro Qualitative Analysis, The National Pub. Co., 1974

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	MAHATMA GANDHI UNIVERSITY **Chemistry of Natural Products**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc. Nanoscience and Nanotechnology**
Course Name	**Chemistry of Natural Products**
Type of Course	**Elective Course**
Credit Value	2
Course Code	**NSM21E46**
Course Summary & Justification	Learning this course will provide a strong foundation in natural products such as carbohydrates, proteins and peptides, fatty acids, nucleic acids, terpenes, steroids and alkaloids. Also provide knowledge about biogenesis of terpenoids and alkaloids. Students will be able to study the synthesis of a series of constituents such as camphor, atropine, papaverine, quinine, cyanin, quercetin, β-carotene, testosterone along with biosynthesis of PGE2 and PGF2α, structure of proteins, nucleic acids and methods for primary structure determination of peptides. This course aims to impart basic knowledge on the replication of DNA, flow of genetic information, protein biosynthesis, transcription and translation, genetic code, regulation of gene expression, DNA sequencing, The Human Genome Project, DNA profiling and the Polymerase Chain Reaction (PCR).
Semester	**I**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours

	Authentic learning, collaborative learning, independent learning	30	30	0	30	90
Prerequisite	Basic knowledge about natural products and DNA					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	The student should be able to understand the natural products such as carbohydrates, proteins and peptides, fatty acids, nucleic acids, terpenes, steroids and alkaloids.	U	1,7
2	Understand the biogenesis of terpenoids and alkaloids	U,A	1,2,4, 7
3	Gather information about to the synthesis of a series of constituents such as camphor, atropine, papaverine, quinine, cyanin, quercetin, β-carotene, testosterone along with biosynthesis of PGE2 and PGF2α, structure of proteins, nucleic acids and methods for primary structure determination of peptides.	U,R	1,2,4, 6
4	Understand basic knowledge on the replication of DNA, flow of genetic information, protein biosynthesis, transcription and translation, genetic code, regulation of gene expression	U	1,2,3
5	Able to understand DNA sequencing, The Human Genome Project, DNA profiling and the Polymerase Chain Reaction (PCR).	U,A	1,2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	Natural products,Carbohydrates, proteins and peptides, fatty acids, nucleic acids, terpenes, steroids and alkaloids, Biogenesis of terpenoids and alkaloids.	**10**	**1-3**

Module 2	Syntheis:Synthesis of camphor, atropine, papaverine, quinine, cyanin, quercetin, β-carotene, testosterone, biosynthesis of PGE2 and PGF2α, 5. 3 Structure of proteins, nucleic acids and methods for primary structure determination of peptides (Nterminal - Sanger's method and Edmond's method; C-terminal - Akabora method and carboxy peptidase method).	**10**	**4,5**
Module 3	Replication of DNA**,** flow of genetic information, protein biosynthesis, transcription and translation, genetic code, regulation of gene expression,	**10**	**5,6**
Module 4	DNA sequencing, The Human Genome Project, DNA profiling and the Polymerase Chain Reaction (PCR).	**10**	**7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **K.Continuous Internal Assessment (CIA)** • Surprise test • Internal Test – Objective and descriptive answer type • Submitting assignments • Seminar Presentation – select a topic of choice in the concerned area and present in the seminar
	L.Semester End examination

References:

1. L Finar, Organic Chemistry, Volume 2: Stereochemistry and The Chemistry Natural Products, 5/E
2. W. Carruthers, I. Coldham, Modern Methods of Organic Synthesis, Cambridge University Press, 2004

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	MAHATMA GANDHI UNIVERSITY
	Spectroscopic Methods in Chemistry
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Spectroscopic Methods in Chemistry**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E47**

Course Summary & Justification	Over the last few decades, spectroscopic techniques have grown into a vital instrument for chemical analysis, structure determination, and the study of dynamics in organic, inorganic, material science, and biological systems. Spectroscopic techniques are widely used to correctly investigate the chemical structure of an analyte. In each spectroscopic mathods (eg. UV-Vis, IR, microeave, NMR, Mass, ESR etc.) the electromagnetic radiation is allowed to interact with the molecule. The electric and magnetic property of the radiation is interacted with the atomic, molecular, and structural properties of the substance. Hence, the analyte is identified and characterized for the presence of atoms, bonds, functional groups, basic nucleus, nuclear spin, electron spin, molecular formula, and molecular weight.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		30	30	0	30	90
Pre-requisite	Basic knowledge about the interaction of electromagnetic radiation with matter involving either absorption, emission, or scattering of radiation.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Elucidate the structure of an unknown organic compound using data from various spectroscopic techniques.	U,A	1,2,7
1	Basic principles of spectroscopy, interaction of electromagnetic radiation with matter, atomic and molecular spectroscopy	U	3,4,5
2	Selection rules and allowed transitions, factors effecting the molecular andelectronic transitions	U,A	3,4
3	Different laws and principles like Beer-Lamberts Law, Frank-Condon principle, Woodward-Fieser rules, Raman Effect, Mössbuer effect etc	U,R	1,2,7
4	Understand the basics of UV-Visible spectroscopy Learn to derive structural information from the UV-Vis. Spectra of various molecules Understand the applications of this UV technique for various purposes.	U	4,5,6
5	Become aware of starching and banding of various bonds.Understand the role of Vibrational spectroscopy in functional group identification.Interpretation of organic and inorganic compounds using IR spectra.Characterization of various molecules.	U	4,5,6
6	Understand the role of Raman spectroscopic techniques for the characterization of materials Learn the applications of Raman spectroscopy.	U,A	4,5,6
7	Understand the basic principle of NMR spectroscopy, able to interpret the NMR spectrum of organic compounds.	U, An	2,3,4,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	**Foundations of Spectroscopic Techniques and Electronic Spectroscopy** Electromagnetic radiation, interaction of electromagnetic radiation with matter, Regions of	**10**	**1-3**

	the electromagnetic radiation, origin of spectrum, Jablonski diagram, intensity of absorption, transition probabilities, Born Oppenheimer approximation. Term symbols of diatomic molecules, selection rules, vibrational coarse structure and rotational fine structure of electronic spectrum, Franck-Condon principle, predissociation, Factors influencing the Electronic Spectroscopy. Application in uv-visible spectroscopy, Woodward-Fieser rules, calculation of heat of dissociation, Birge and Sponer method, Electronic spectra of polyatomic molecules.		
Module 2	Infrared and Raman Spectroscopy Morse potential energy diagram, fundamental vibrations, overtones and hot bands, determination of force constants, Factors influencing the vibrational frequency, Vibrations in simple molecules (H2O, CO2) and their symmetry notation for molecular vibrations – combined uses of IR and Raman spectroscopy in the structural elucidation of simple molecules. Vibrational spectra of polyatomic molecules, normal modes of vibrations, combination and difference bands, Fermi resonance, FT technique, introduction to FTIR spectroscopy, scattering of light, polarizability and classical theory of Raman spectrum, P, Q, R branches, rotational and vibrational Raman spectrum, complementarities of Raman and IR spectra, mutual exclusion principle, polarized and depolarized Raman lines, resonance Raman scattering and resonance fluorescence.Lasers-Different types of lasers-solid state lasers, continuous wavelasers, Nd:YAG and semiconductor lasers, gas lasers – helium-neon, argon ion and N2 lasers, frequency doubling, harmonic generation,applications of lasers.	**10**	**4,5**

	Applications of lasers in spectroscopy: twophoton and multiphoton absorption, femtosecond spectroscopy.		
Module 3	**Microwave, ESR, and Mass Spectroscopy** Principal moments of inertia and classification (linear, symmetric tops, spherical tops and asymmetric tops), selection rules, intensity of rotational lines, relative population of energy levels, derivation of Jmax, effect of isotopic substitution, calculation of intermolecular distance, spectrum of non-rigid rotors, Rotational spectra of polyatomic molecules, linear and symmetric top molecules, Stark effect and its application, nuclear spin and electron spin interaction, chemical analysis by microwave spectroscopy. Elementary idea about Mass and ESR spectrometry, interpretation of data and solving problems with spectroscopic techniques.	**10**	**5,6**
Module 4	**NMR Spectroscopy:** 1H NMR, Spectral parameters – intensity, chemical shift, multiplicity, coupling constant, factors affecting chemical shift, characteristic chemical shifts of common organic compounds and functional groups. Analysis of first order and second - orderspectra – shift reagents - structure determination of organic compounds by 1H NMR spectra. Classification of molecules. (AB, ABX, AMX, ABC, A2B2 etc. types), spin decoupling. Chemical shifts and coupling constants (spin-spin coupling) involving different nuclei (1H, 13C).	**10**	**7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

REFERENCES

1. Banwell C. N.; McCash, E. M., Fundamentals of Molecular Spectroscopy, Tata
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5. Kemp, W., Organic Spectroscopy, Macmillan (2011).
6. Aruldas, G., Molecular Structure and Spectroscopy, 2 nd Ed., Prentice Hall India (2001).
7. Nakamoto, K., Infrared and Raman Spectra of Inorganic and Coordination compounds, Wiley-Interscience, New York (2008).
8. Gunther, H., and NMR Spectroscopy: Basic Principles, Concepts and Applications in Chemistry, 2 nd Ed., John Wiley & Sons (1995).
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	MAHATMA GANDHI UNIVERSITY

	Polymer Chemistry

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
CourseName	**Polymer Chemistry**
Type of Course	**Elective**
CreditValue	2
CourseCode	**NSM21E48**

Course Summary& Justification	Polymer chemistry is a distinctive topic in chemistry having many inter as well as multidisciplinary components. This course is designed as an interdisciplinary course that includes fundamental as well as in-depth knowledge of the polymer science. The syllabus has been designed to cover the fundamental understanding of different fields of polymer chemistry with special emphasis on polymer synthesis and related topics thereby enable the students to work in frontier areas of polymer sciences. This comprises of the history of polymer science and its relevance in the development of human civilization. The syllabus covers the significance polymer molecular weight and its relation with structure and property of various polymers. This course also covers detailed study of the polymerisation reactions and techniques for polymer synthesis. This course further offers an awareness and understanding of the contemporary trends and growth in the field of polymer science. After the completion of this course, students will be able to understand the basics associated with polymer materials and the method/mechanism of its synthesis.					
Semester	**I**					
Total StudentLearningTime (SLT)	LearningApproach	Lecture	Tutorial	Practical	Others	Total LearningHours
	Lectures, Groupdiscussions, Seminars, IndependantLearningetc..	30	30	0	30	90
Pre-requisite	UnderstandingofOrganicChemistry (Undergraduatelevel).					

COURSE OUTCOMES (CO)

CO No.	ExpectedCourseOutcome	LearningDomains	PSO No.
1	To Acquire a sound knowledge about the fundamentals and importance of Polymer chemistry.	R, U, An	1,2, 3,7
2	To compare and correlate various polymerization reactions and techniques.	U, A, An	2,3
3	To understand the peculiarities of polymer molecular weight and various determination techniques.	U, A	1,2
3	To Correlate the structure and property relationship in polymeric materials.	An	1,4, 5
	To outline the basic concepts of thermal transitions in polymers and the determination methods for it.	U, A, An	1,2, 3
5	To understand and explore properties andadvance applications of different polymers in diverse areas.	U, A, An, E	1,2, 3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	Concept of polymer & macromolecules, definition, functionality, classification of polymers. Polymerization reactions: Addition (free radical polymerization reaction, anionic and cationic polymerization, coordination polymerization, Ziegler Natta polymerization) and Condensation polymerization, Co-polymerization. Polymerization techniques: Bulk, solution, suspension, emulsion polymerizations, melt and interfacial polycondensations.	**10**	**1-3**

Module 2	**Concept of molecular weight of polymers**: number average, weight average, Z average and viscosity average molecular weight, molecular weight distribution and polydispersity index (PDI). Determination of molecular weight of polymers: Light scattering technique, Membrane Osmometry, Gel permeation chromatography (GPC), viscometry, etc.	**10**	**4,5**
Module 3	Crystalline and amorphous polymers, Factors affectingcrystallinity and chain flexibility of polymers. Effect of Crystallinity on the properties of polymers. Thermal transitions in polymers: Glass transition temperature (T_g) and crystalline melting points (T_m), Factors affecting Glass transition temperature, methods to determine T_g and T_m: DSC, TMA, DMA etc.	**10**	**5,6**
Module 4	Properties and Applications of: Specialty Polymers,Poly electrolytes, ionomers (ion containing polymers), conducting polymers, electroluminescent polymers, fluoropolymers, polymer colloids, thermoplastic elastomers (TPE), polymer blends (heterogeneous plastics), thermally stable polymers, biomedical polymers.	**10**	**7,8**

Teachingand LearningApproach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
AssessmentTypes	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test

	➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

REFERENCES

1. V.R. Gowariker, N.V. Viswanathan, J. Sreedhar, Polymer Science, New Age International, 2010
2. P. Bahadur, N. V. Sastry, Principles of Polymer Science, Narosa publishing house Pvt. Ltd., New Delhi, 2005.
3. M. S. Bhatnagar, A Textbook of Polymers, Vol II, S. Chand & Company Ltd., 2004.
4. Premamoy Ghosh, Fibre Science & Technology, McGraw-Hill professional, 2004.
5. D. C. Blackley, Polymer lattices: Science and Technology, Springer Netherlands, 2012
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7. G.G. Odian, Principles of Polymerization, 4th Edn, John Wiley & Sons, 2004.
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MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Chemical Kinetics**
Type of Course	**Elective**
Credit Value	**2**

Course Code	NSM21E49

Course Summary & Justification	This course introduces students to the core area of various theories of reaction rates and thermodynamic formulation of the reaction rate. Students will gain an in-depth understanding of the effect of pressure and volume on velocity of gas reactions. Chain initiation processes, kinetics of H2-Cl2 and H2-Br2 reactions and mechanism of branching chains are also included in this course. A detailed study of fast reactions, factors determining reaction rates in solutions and primary and secondary kinetic salt effect is offered to the students. The course discusses the acid-base catalysis, mechanism with examples, enzyme catalysis and its mechanism. The course will also cover the introduction to oscillating chemical reactions, autocatalysis and mechanism of oscillating reactions.
Semester	**I**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, collaborative learning, independent learning	20	40	0	20	80
Pre-requisite	Basic knowledge about chemical kinetics (undergraduate level)					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome Upon completion of this course, students will be able to;	Learning Domains	PSO No.
1	Understand the various theories of reaction rates and significance of $\Delta G^{\neq}$, $\Delta H^{\neq}$ and $\Delta S^{\neq}$ and volume of activation	U	1,2
2	Able to understand the effect of pressure and volume on velocity of gas reactions	U,A	1, 3
3	Describe the chain initiation process and mechanism of branching chains	U,R	1,2,3
4	Explain the kinetics of step growth, free radical, cationic and anionic polymerization reactions	U	1,2,3,4
5	Understand the importance of NMR and ESR methods of studying fast reactions	U,A	3,4,5,6

6	Gather knowledge about the effect of dielectric constant and ionic strength, cage effect, Bronsted-Bjerrum equation, primary and secondary kinetic salt effect	U,R	1,2,3
7	To study prototropic and protolytic mechanism with examples, enzyme catalysis and its mechanism	U,A	3,4,5,6
8	Able to learn the autocatalysis, autocatalytic mechanism of oscillating reactions	U, R	3,4,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	**Theories of reaction rates:**Collision theory, kinetic theory of collisions, steric factor, potential energy surfaces, Conventional transition state theory, thermodynamic formulation of the reaction rate-Eyring equation, Comparison of the two theories. **Significance of ΔG≠, ΔH≠ and ΔS≠, volume of activation,** Effect of pressure and volume on velocity of gas reactions, Unimolecular reactions: Lindemann- Hinshelwood mechanism, qualitative idea of RRKM theory.	**10**	**1-3**
Module 2	**Chain reactions:**Chain initiation processes, steady state treatment, kinetics of H_2-Cl_2 and H_2-Br_2 reactions, Rice-Herzfeld mechanism for decomposition of ethane and acetaldehyde, Goldfingr-Letort-Niclause rules, branching chains, Semenov Hinshelwood mechanism of branching chains, upper and lower explosion limits, the H2O2 reaction, kinetics of step growth, free radical, cationic and anionic polymerization reactions.	**10**	**4,5**
Module 3	**Fast reactions:**Relaxation, flow and shock methods, flash photolysis, NMR and ESR methods of studying fast reactions, Reactions in solution: Factors determining reaction rates in solutions, effect of dielectric constant and ionic strength, cage effect, Bronsted-Bjerrum equation, primary and secondary kinetic salt effect.	**10**	**5,6**

Module 4	**Acid-base catalysis:** Specific and general catalysis, Skrabal diagram, Bronsted catalysis law, prototropic and protolytic mechanism with examples, acidity function, Enzyme catalysis and its mechanism, Michelis-Menten equation, effect of pH and temperature on enzyme catalysis. **Introduction to oscillating chemical reactions:** autocatalysis, autocatalytic mechanism of oscillating reactions, the Lotka-Volterra mechanism, the brusselator, the oreganator, bistability.	**10**	**7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **I. Continuous Internal Assessment (CIA)** ○ Surprise test ○ Internal Test – Objective and descriptive answer type ○ Submitting assignments ○ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **J. Semester End examination**

References:

1. J. Rajaram, J. C. Kuriakose, Kinetics and Mechanisms of Chemical Transformations, Macmillan India, 2000
2. K. J. Laidler, Chemical kinetics, 3rdEdn. , Harper & Row, 1987
3. C. Kalidas, Chemical Kinetic Methods: Principles of Fast Reaction Techniques and Applications, New Age International, 2005
4. J. W. Moore, R. G. Pearson, Kinetics and Mechanisms, John Wiley & Sons, 1981
5. P. W. Atkins, Physical Chemistry, 9th Edn, Oxford University press, 2010
6. D. A. McQuarrie, J. D. Simon, Physical chemistry: A Molecular Approach,University Science Books,1997
7. A. W. Adamson, A. P. Gast, Physical Chemistry of Surfaces, 6thEdn., John Wiley & sons, 1997

	MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**					
Programme	**M.Sc.**					
Course Name	**Analytical Chemistry**					
Type of Course	**Elective**					
Course Credit	**2**					
Course Code	**NSM21E50**					
Course Summary & Justification	This course essentially encompasses two components. The first component is the advanced course materials on general analytical chemistry instruments, operation, sampling and their applications. Here the some modern instruments which works under the principle of fluorescence are discussed in order to get an understanding on the present and future applications of these fluorescence microscopes in the field of medicine. In addition a concise discussion on specific sampling methods and titrations in non-aqueous media are also included as an application of analytical chemistry.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lectur e	Tutori al	Practica l	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	30	30	0	30	90
Credit Value & Course Status	2	Elective Course				
Pre-requisite	Basic Inorganic Chemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.

1	Understand the methods used in sampling for various analytical methods.	U	1,2
2	Learn about the general instrumentation in thermal analysis, chromatography and microscopy	U	1, 2
3	Identify the utility and specificity of each analytical instrument and will be in a position to generate and explain the output data from the analytical instruments.	An	1, 2, 3,7
4	Critically understand the applications of X-ray diffraction, Small angle X-ray scattering (SAXS), Scanning electron microscopy (SEM), Transmission electron Microscopy (TEM), Scanning probe microscopy (SPM)	U	1, 2, 3
5	Evaluate the utility of ion-exchange, Solvent extraction, Chromatographic techniques,.	E	1, 2, 3,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	Preparation of sample for analysis, Errors and treatment of data, Solubility and solubility product, Common ion effect, Precipitation phenomena, Homogeneous precipitation, Organic reagents in inorganic analysis.	**10**	**1-3**
Module 2	Titrations in non-aqueous media, Potentiometry, Polarography, Amperometry, Bi-amperometry, Spectrophotometry, Flame photometry, Atomic absorption spectroscopy.	**10**	**4,5**

Module 3	Applications of X-ray diffraction, Small angle X-ray scattering (SAXS), Scanning electron microscopy (SEM), Transmission electron Microscopy (TEM), Scanning probe microscopy (SPM).	**10**	**5,6**
Module 4	Principles of ion-exchange, Solvent extraction, Chromatographic techniques, Thermal method of analysis: Principles and applications of thermogravimetry (TG), Differential thermal analysis (DTA), Differential scanning calorimetry (DSC), Dynamic mechanical analysis (DMA).	**10**	**7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** 1. Direct Instruction: Lecture, Explicit Teaching, E-learning 2. Interactive Instruction:, Active co-operative learning, Seminar/ Presentation by individual student, Assignments, Authentic learning, Quizzes
Assessment Types	**Mode of Assessment** A. Continuous Internal Assessment (CIA) • Internal Test – MCQ based and descriptive answer type • Seminar Presentation – the students will be given individual topics for seminar presentation • Assignments • Quizzes B. **Semester End examination**

References

01. A.I. Vogel, J. Mendhan, Vogel's Texbook of Quantitative Inorganic Analysis, 6thEdn., Prentice Hall, 2000.

02. D.A. Skoog, D.M. West, F.J. Holler, Fundamentals of Analytical Chemistry, 7thEdn., Sauders College, 1996.

03. W.W. Wendlandt, Thermal Analysis, 3rdEdn., Wiley, 1986.

04. G. Cao, Y.Wang, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, World Scientific, 2010.

	MAHATMA GANDHI UNIVERSITY
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Chemical Thermodynamics**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E51**

Course Summary & Justification	The course gives a thorough description of the laws of thermodynamics, as well as chosen subjects within thermodynamic laws. The course builds on fundamental concepts in thermodynamics. Topics covered include Topics covered are Classical thermodynamics, different rate laws, equation of state, molecular phenomenon of mixing and chemical affinity. Throughout the course, the relationship between physical phenomena and the molecular structure and reactions underpinning advanced materials will be highlighted. The course also contains a laboratory part where some parts of the theoretical syllabus is illustrated. In addition, the laboratory course provides the students with hands-on experience with assessing the uncertainty of qualitative measurement data.This course introduces students to the core area of physical chemistry, based around the themes of systems, states and processes. The general goal of learning physical chemistry is to obtain an in-depth understanding of why and how chemical reactions occur, which in turn may enable us to accurately design reactions leading to novel molecules of the future.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		30	30	0	30	90
Pre-requisite	Thermodynamics and partial molar quantities (Undergraduate level). Strong mathematical skill in Differential Equations and Linear Algebra.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Explain thermodynamic laws, variables and functions and their practical significance	U	2,7
2	Describe the use of simple models for predictive understanding of different molecular systems and phenomena.	U, A	1,2
3	Derive important thermodynamic relations	U, R	1,2
4	Understand a comprehensive and rigorous treatment of classical thermodynamics.	U	2
5	Understand transformations at the molecular level.	U	1,3,6
6	Perform numerical calculations of thermodynamic variables .	U, A	4
7	State and apply basic concepts of thermodynamics into mixtures, Understand thermodynamics of ideal and non-ideal solutions.	U, An	2,4
8	Find the connection between statistics and thermodynamics and differentiate between different ensemble theories used to explain the behaviour of the systems.	U, A, An	1,2,5
9	To understand the properties of macroscopic systems using the knowledge of the properties of individual particles, thermodynamic probability, macroscopic and microscopic states.	U, A	2,3
10	Apply thermodynamic principles to analyze practical problems .	U, A	1,2
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Module No:	Module Content	Hrs	CO. No.

Module 1	**Mathematical foundations for thermodynamics**-variables of thermodynamics, extensive and intensive quantities, equation for total differential, conversion formulas, exact differentials-general formulation, reciprocity characteristics, homogeneous functions, Euler's theorem, (Non-evaluative), **Thermodynamic equations of state,** Maxwell relations and significance, irreversible processes - Clausius inequality. **Free energy,** thermodynamic equilibria and free energy functions, temperature dependence of free energy - Gibbs Helmholtz equation, applications of Gibbs Helmholtz equation.	**10**	**1-3**
Module 2	**Partial molar quantities,** chemical potential and Gibbs-Duhem equations, variation of chemical potential with temperature and pressure, determination of partial molar volume and enthalpy, Fugacity, relation between fugacity and pressure, determination of fugacity of a real gas, variation of fugacity with temperature and pressure, Activity, dependence of activity on temperature and pressure.	**10**	**4,5**
Module 3	**Thermodynamics of mixing,** Gibbs- Duhem - Margules equation, applications of Gibbs Duhem-Margules equation- Konovalov's first and second laws, excess thermodynamic functions-free energy, enthalpy, entropy and volume, determination of excess enthalpy and volume. **Chemical affinity** and thermodynamic functions, effect of temperature and pressure on chemical equilibrium- Vant Hoff reaction isochore and isotherm.	**10**	**5,6**
Module 4	**Third law of thermodynamics**, Nernst heat theorem, determination of absolute entropies using third law. **Three component systems**-graphical representation, Solid-liquid equilibria, ternary solutions with common ions, hydrate formation, compound formation, Liquid-liquid equilibria-one pair of partially miscible liquids, two pairs of partially miscible liquids, three pairs of partially miscible liquids.	**10**	**7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

References:

1.Irving M. Klotz, Robert M. Rosenberg, Chemical Thermodynamics,John Wiley &SonsINC Publication,2008

2.R. P. Rastogi, R. R.Misra, An introduction to Chemical Thermodynamics, Vikas publishing house, 1996

3.J. Rajaram, J. C. Kuriakose, Thermodynamics, S Chand and Co., 1999

4.M. W.Zemansky, R. H.Dittman, Heat and Thermodynamics, Tata McGraw Hill,1981

5.P. W. Atkins, Physical Chemistry, ELBS, 1994

SEMESTER 2

MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**

Course Name	**Statistical thermodynamics**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C64**

Course Summary & Justification	This course introduces students to the core area of physical chemistry, based around the themes of systems, states and processes. Topics covered are Quantum mechanics, Classical thermodynamics, Statistical mechanics and Chemical kinetics. Throughout the course, the relationship between physical phenomena and the molecular structure and reactions underpinning advanced materials will be highlighted.The general goal of learning physical chemistry is to obtain an indepth understanding of why and how chemical reactions occur, which in turn may enable us to accurately design reactions leading to novel molecules of the future.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Basic knowledge in statistical mechanics, thermodynamics and kinetics (Undergraduate level).					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome Upon completion of this course, students will be able to;	Learning Domains	PSO No.
1	Understand the brief history about the macroscopic and microscopic approach in science	U	1,2
2	Understand the macrostates and microstates, equal-apriori principle and thermodynamic probability, phase-space, ensemble, types of ensembles	U,A	1,2,3
3	Understand Boltzmann distribution law, partition function and its physical significance	U,R	3,4
4	To understand the calculation of thermodynamic functions and equilibrium constants	U	1-4

5	To study quantum statistics, Bosons and Fermions, Bose-Einstein statistics	U	1,2,5
6	To study heat capacity of solids- the vibrational properties of solids, Einstein's theory and its limitations, Debye theory and its limitations	U,A	1-6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	Brief history about the macroscopic and microscopic approach in science, permutation, probability, Stirling's approximation, macrostates and microstates, equal-apriori principle and thermodynamic probability, phase-space, ensemble, types of ensembles	**15**	**1,2**
Module 2	Boltzmann distribution law, partition function and its physical significance, relation between molecular partition function and molar partition function, distinguishable and indistinguishable particles, partition function and thermodynamic functions, separation of partition function- translational, rotational, vibrational, and electronic partition functions, partition function for hydrogen,Thermal de-Broglie wavelength	**15**	**1,3**
Module 3	**Calculation of thermodynamic functions and equilibrium constants**, thermodynamic probability and entropy, Sakur-Tetrode equation, statistical formulation of third law of thermodynamics, residual entropy, heat capacity of gases - classical and quantum theories.	**15**	**4**

Module 4	Need for quantum statistics, Bosons and Fermions, Bose-Einstein statistics:Bose- Einstein distribution law, Bose-Einstein condensation, first order and higher order phase transitions, liquid helium, Fermi-Dirac statistics: Fermi- Dirac distribution law, application in electron gas, thermionic emission, Comparison of three statistics. Heat capacity of solids- the vibrational properties of solids, Einstein's theory and its limitations, Debye theory and its limitations.	**15**	**5,6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **M. Continuous Internal Assessment (CIA)** • Surprise test • Internal Test – Objective and descriptive answer type • Submitting assignments • Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **N. Semester End examination**

References:

1. F. W.Sears, G. L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Addison Wesley, 1975
2. J. Kestin, J. R. Dorfman, A Course in Statistical Thermodynamics, AcademicPress, 1971
3. M. C. Gupta, Statistical Thermodynamics, New age international, 2007
4. L. K. Nash, Elements of Classical and Statistical Mechanics,2ndEdn., Addison Wesley, 1972

MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**

Course Name	**Organo metallic chemistry, Bio inorganic chemistry**
Type of Course	**Core**
Kredit Value	**3**
Course Code	**NSM21C65**

Course Summary & Justification	This course introduces the basic concepts of organometallic chemistry with emphasis on transition metal complexes. The students will understand the structure and bonding of organometallic complexes bearing various σbonded and π-bonded ligands. They will learn about the unique reactions shown by organometallic compounds and its mechanism. This course highlights the application of organometallics in catalysis that is industrially important This course provides the students a detailed knowledge on fundamental aspects of the bioinorganic chemistry. The students will understand the role of metal ions and inorganic complexes in biological processes. They will learn about metal toxicity as well as the application of inorganic complexes as therapeutics. This course will give a strong foundation to carry out research on metalloenzyme applications, inorganic biomaterials and pharmaceutical development.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Basic knowledge in Inorganic Chemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome Upon completion of this course, students will be able to;	Learning Domains	PSO No.
1	Understand the fundamental concepts of organometallic complexes such as 18 electron rule.	U	1,2,3
2	Explain and rationalize the structure and bonding of organometallic compounds with σ- and πbonded ligands	U,A	1,2
3	Apply spectroscopic techniques to characterize organometallic compounds	U,R	3-6

4	Identify the fundamental reactions of organometallic compounds and its mechanism.	U	1, 4, 5
5	Describe the application of organometallics in catalysis	U	7,8
6	Apply the basic principles in inorganic and general chemistry to bioinorganic chemistry.	U,A	1,3, 8
7	Understand the importance of metals in biological systems.	U, An	1, 2, 3, 6
8	Remember the structure and functions of metalloproteins and metalloenzymes	U, A, An	5, 9
9	Explain the role of metal ions which are involved in electron transfer reactions in biological systems.	U, A	2, 4, 5
10	Identify the metal centers involved in oxygen transport in living organisms and comprehend the mechanism of this process.	U, A	2, 3, 5
11	Understand the biological role of Iron, copper, zinc and molybdenum	U	1, 2,3
Remember I, Understand (U), Apply (A), Analyse (An), Evaluate I, Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	**Organometallic Compounds**Synthesis, Structure and Bonding, Hapto nomenclature of organometallic compounds, organometallic compounds with linear pi donor ligands-olefins, acetylenes, dienes and allyl complexes-synthesis, structure and bonding, Synthesis and structure of complexes with cyclic pi donors, metallocenes and cyclic arene complexes, bonding in ferrocene and dibenzene chromium, carbene and carbyne complexes, Metal carbonyls: CO as a π-bonding ligand, synergism, preparation, properties, structure and bonding of simple mono and binuclear metal	**15**	**1-3**

	carbonyls, metal nitrosyls, metal cyanides and dinitrogen complexes, Polynuclear metal carbonyls with and without bridging, Carbonyl clustersLNCCS and HNCCS, Isoelectronic and isolobal analogy, Wade-Mingos rules, cluster valence electrons, IR spectral studies of bridging and nonbridging CO ligands.		
Module 2	**Reactions of Organometallic Compounds**, Substitution reactions: Nucleophilic ligand substitution, nucleophilic and electrophilic attack on coordinated ligands, Addition and elimination reactions-1,2 additions to double bonds, carbonylation and decarbonylation, Oxidative addition- concerted addition, SN2, radical and ionic mechanisms, Reductive elimination- binuclear reductive elimination and σ-bond metathesis, Oxidative coupling and reductive decoupling, Insertion (migration) and elimination reactions – insertions of CO and alkenes, insertion into M−H versus M−R, α, β, γ and δ eliminations, Redistribution reactions, fluxional isomerism of allyl, cyclopentadienyl and allene systems.	**15**	**4**
Module 3	Catalysis by Organometallic Compounds, Homogeneous and heterogeneous organometallic catalysis: Tolman catalytic loops, alkene hydrogenation using Wilkinson catalyst, Reactions of carbon monoxide and hydrogen-the water gas shift reaction, the FischerTropsch reaction (synthesis of gasoline), Hydroformylation of olefins using cobalt and rhodium catalysts, Polymerization by organometallic initiators and templates for chain propagation Ziegler Natta catalysts, polymerisation by metallocene catalysts,arbonylation reactions:	15	5

	Monsanto acetic acid process, olefin hydroformylation- oxo process, carbonylation of alkenes and alkynes in the presence of a nucleophile-the Reppe reaction, Carbonylation of aryl halides in the presence of a nucleophile. Olefin metathesis-synthesis gas-based reactions, photodehydrogenation catalyst ("Platinum Pop"), Oxidation of olefins: Palladium catalyzed oxidation of ethylene-the Wacker process, epoxidation of olefins, hydroxylation by metal-oxo complexes, Asymmetric catalysis- Asymmetric hydrogenation, isomerization and epoxidation, C-H activation and functionalization of alkanes and arenes: Radicaltype oxidation, hydroxylation, dehydrogenation, carbonylation and regioselective borylation of alkanes and cycloalkanes,Radicaltype reactions, electrophilic reactions, carbonylation and borylation of arenes, Insertion of alkenes and alkynes in the Ar-H bond, Application of palladium catalysts in the formation of C-O and C-N bonds,oxidative coupling reactions of alkynes with other unsaturated fragments for the formation of cyclic and heterocylic compounds, The Dötz reaction.		
Module 4	**Bioinorganic Compounds** Essential and trace elements in biological systems, toxic effects of metals (Cd, Hg, Cr,Pband As), structure and functions of biological membranes, mechanism of ion transport across membranes, sodium pump, ionophores, valinomycin, Phosphate esters in biology, Redox metalloenzymes, cytochromescytochrome P450, Oxygen carriers and oxygen transport proteins: Structure and functions of haemoglobins and myoglobin, oxygen transport mechanism, cooperativity, Bohreffect, Structure and functions of haemerythrinsandhaemocyanin, Biochemistry of zinc and copper: Structure and functions of carbonic anhydrase, carboxypeptidase A and superoxide dismutase. **Other important metal containing biomolecules:** Vitamin B12 and the vitamin B12 coenzymes, photosynthesis-chlorophyll a, PS I and PS II, Role of	15	6-10

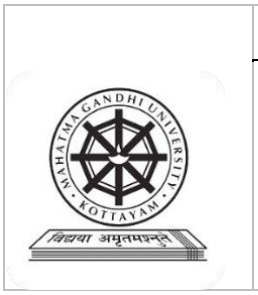
	calcium in muscle contraction, blood clotting mechanism and biological calcification, Metals in medicine-therapeutic applications of cis-platin, radioisotopes and MRI agents.		

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** oInternal Test – MCQ based and descriptive answer type o Seminar Presentation – the students will be given individual topics for seminar presentation o Assignments oQuizzes **B. Semester End examination**

References:

1. J. E. Huheey, E. A.Keiter, R. L. Keiter, Inorganic Chemistry Principles of Structure and Reactivity, 4th Edn., Harper Collins College Publishers,1993
2. F. A. Cotton, G. Wilkinson, C. A. Murillo, M.Bochmann, Advanced Inorganic Chemistry, 6th edition, Wiley-Interscience, 1999
3. K. F. Purcell, J. C. Kotz, Inorganic Chemistry, Holt-Saunders, 1977

4. P. Powell, Principles of Organometallic Chemistry, 2ndEdn., Chapman and Hall, 1988
5. B. E. Douglas, D. H. McDaniel, J. J.Alexander, Concepts and Models of Inorganic Chemistry, 3rdEdn., Wiley-India, 2007
6. B. D. Guptha, A. J Elias, Basic Organometallic Chemistry, Universities Press, 2010
7. R. W. Hay, Bio Inorganic Chemistry, Ellis Horwood, 1984
8. SumitBhaduri, Doble Mukesh, Homogeneous Catalysis: Mechanism and Industrial Applications, Wiley Interscience, 2000
9. Astruc, D.; Organometallic Chemistry and Catalysis, Springer Verlag, 2007
10. Robert H.Crabtree, The Organometallic Chemistry of the Transition Metals, 4thEdn., Wiley Interscience, 2005



MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Nuclear chemistry: nuclear reactions, fission and fusion, radioanalytical techniques and activation analysis**
Type of Course	**Core**
Kredit Value	**3**
Course Code	**NSM21C66**

Course Summary & Justification	This course introduces the basic concepts of organometallic chemistry with emphasis on transition metal complexes. The students will understand the structure and bonding of organometallic complexes bearing various σbonded and π-bonded ligands. They will learn about the unique reactions shown by organometallic compounds and its mechanism. This course highlights the application of organometallics in catalysis that is industrially important This course provides the students a detailed knowledge on fundamental aspects of the bioinorganic chemistry. The students will understand the role of metal ions and inorganic complexes in biological processes. They will learn about metal toxicity as well as the application of inorganic complexes as therapeutics. This course will give a strong foundation to carry out research on metalloenzyme applications, inorganic biomaterials and pharmaceutical development.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Basic knowledge in nuclear chemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome Upon completion of this course, students will be able to;	Learning Domains	PSO No.
1	Understand the nuclear reactions, Q value and reaction threshold	U	1, 2
2	Understand the nuclear fission in detail	U,A,E	1,2,3
3	Understand about the nuclear fusion reactions and their applications	U,R	3,4,5
4	To understand the principles of counting technique such as G. M. counter	U, A, An, E	1, 4
5	To study the synthesis of various transuranic elements	U,A, An	4,5,6

6	Able to gather information on kinetics of exchange reactions	U,A	1, 2,3
7	To study measurement of radiation doses, relevance of radiation chemistry in biology, organic compounds and radiation polymerization	U, An	3,8,9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	**Nuclear Reactions:**Q value and reaction threshold, reaction cross section, cross section and reaction rate, neutron capture cross section	**15**	**1**
Module 2	**Nuclear fission** - fission fragments and mass distribution, fission yields, fission energy, fission cross section and threshold fission neutrons **Nuclear fusion** reactions and their applications, **Principles of counting technique**: G. M. counter, proportional, ionization and scintillation counters, cloud chamber.	**15**	**2,3,4**
Module 3	**Synthesis of transuranic elements**: Neptunium, Plutonium, Curium, Berkelium, Einsteinium, Mendelevium, Nobelium, Lawrencium, Analytical applications of radioisotopes-radiometric titrations, kinetics of exchange reactions, measurement of physical constants including diffusion constants, Radioanalysis, Neutron Activation Analysis, Prompt Gama Neutron Activation Analysis and Neutron Absorptiometry, Radiation chemistry of water and aqueous solutions.	**15**	**5,6**

Module 4	**Measurement of radiation doses,** Relevance of radiation chemistry in biology, organic compounds and radiation polymerization	**15**	**7**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **C. Continuous Internal Assessment (CIA)** oInternal Test – MCQ based and descriptive answer type o Seminar Presentation – the students will be given individual topics for seminar presentation o Assignments oQuizzes **D. Semester End examination**

References:

1. H.J. Arnikar, Essentials of Nuclear Chemistry, Wiley Eastern, 1982
2. G. Fridlander, J.W. Kennedy, E.S. Macias and J.M. Miller, Nuclear & Radiochemistry, John-Wiley & Sons, New York, 3rd Edition,1981
3. Peter A C McPherson, Principles of Nuclear Chemistry, World Scientific, 2017
4. Principals of Physical Chemistry,Puri, Sharma&Pathania, Vishal Publishing Co., 1962
5. S.N. Goshal, Nuclear Physics, S. Chand and Company, 2006
6. Kenneth S. Krane, Introductory Nuclear Physics, Wiley, 1987
7. B. G. Dutt, Fundamental Particles, Taylor Francis, London, 2003

MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Organic Chemistry I-Reaction Mechanisms, Named reactions and common organic reagents**

Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C67**

Course Summary & Justification	Starting from the very basic ideas, and moving towards the classification using different approaches, this course deals with advanced organic reaction mechanisms. The course guides through the involvement of reactive intermediates, their structure and reactivity through various organic reactions, as well as the basic concepts in molecular rearrangement reactions. The course is designed to acquaint the students with a detailed knowledge of physical organic chemistry, and ensures the students to understand and acquire knowledge on pericyclic reactions and name reactions, and their further applications in organic synthesis.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Basics of organic chemistry, stereochemistry, reaction mechanisms and pathways					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome Upon completion of this course, students will be able to;	Learning Domains	PSO No.
1	To revise and analyse the role of reactive intermediates such as carbocations, carbanions and non-classical carbocations in chemical reactions	R, U, An	1,2
2	To assess the reactivity patterns of enolates and their mechanisms	A, An	3,4
3	To synthesize molecules using popularly named reactions	A, C, S	4,5,6

4	To describe reaction mechanisms in terms of energetics, reaction kinetics, and thermodynamics	An, E	2,3,4
5	To predict suitable reaction conditions to carry out organic reactions	E, C, S	2,4,6
6	To have a thorough knowledge about catalysis by acids, bases and nucleophiles	U, I, S, Ap	1, 6
7	To learn basic concepts of pericyclic reactions	U, I, R	1, 2, 3, 5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	**Organic Reaction Mechanisms** Formation, structure and stability of carbanions; Reactions of carbanions: C-X bond (X = C, O, N) formations through the intermediary of carbanions. Chemistry of enolates and enamines. Aldol and Michael reactions, alkylation and acylation of enolates. Nucleophilic additions to carbonyls groups: Name reactions under carbanion chemistry-mechanism of Claisen, Dieckmann, Knoevenagel, Stobbe, Darzen and acyloin condensations, Shapiro reaction and Julia olefination. Favorskii rearrangement. Ylides: Chemistry of phosphorus and sulphur ylides - Wittig and related reactions, Peterson olefination. Formation, structure and stability of carbocations. Classical and non-classical carbocations. C-X bond (X = C, O, N) formations through the intermediary of carbocations. Molecular rearrangements including Wagner-Meerwein, Pinacol-pinacolone,	**15**	**1,2**

	Semipinacol, Dienone-phenol and Benzilic acid rearrangements, Noyori annulation, Prins reaction. C-C bond formation involving carbocations: Oxymercuration, Halolactonization.		
Module 2	**Named reactions in Organic Chemistry** Reimer-Tiemann, Cannizzaro, Mannich, Demjanov and Mitsunobu reactions, Aldol condensation, Robinson annulation Addition reactions: Addition of Grignard reagent, Michael addition Reduction reactions: Clemmensen, Wolf-Kishner, MPV Rearrangement reactions: Wolff, Hoffmann, Curtius, Lossen, Schmidt and Beckmann, Fries and Fischer-Hepp.	**15**	**3**
Module 3	**Physical Organic Chemistry** Energy profiles, Kinetic versus thermodynamic control of product formation, Hammond postulate, kinetic isotope effects with examples, Linear free energy relationships-Hammet equation, Taft equation. Catalysis by acids, bases and nucleophiles with examples from acetal, cyanohydrin, Ester formation and hydrolysis reactions of esters - AAC2, AAC1, AAL1, BAC2 and BAL1 mechanisms, Hard and soft acids, bases - HSAB principle and its applications (organic reactions only)	**15**	**4-6**
Module 4	**Pericyclic reactions** Introduction to pericyclic reaction, Cycloaddition and Diels –Alder reactions, Electrocyclic reactions, Sigmatropic reactions, Chelotropic reactions. Thermal and photochemical pericyclic reactions, Conrotation and disrotation; Electrocyclic closure and opening in 4n and 4n+2 systems.	**15**	**7**

	WoodwardHoffmann selection rules for electrocyclic reactions. Explanation for the mechanism of electrocyclic reactions and examples. Cycloaddition reactions: Suprafacial and antarafacial interactions. $2\pi + 2\pi$ and $4\pi + 2\pi$ cycloadditions. Diels-Alder reaction, Woodward-Hoffmann selection rules for cycloaddition reactions and examples. Mechanism by orbital symmetry correlation diagrams, Fukui Frontier Molecular Orbital (FMO) theory. Endoexo selectivity in Diels-Alder reaction and its explanation by FMO theory. Sigmatropic reactions: mechanism of sigmatropic reactions, Cope and Claisen rearrangements.		

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **E. Continuous Internal Assessment (CIA)** oInternal Test – MCQ based and descriptive answer type o Seminar Presentation – the students will be given individual topics for seminar presentation o Assignments oQuizzes **F. Semester End examination**

References:

1) R. Bruckner, Advanced Organic Chemistry: Reaction Mechanism, Academic Press, 2002.

2) F.A. Carey, R.A. Sundberg, Advanced Organic Chemistry, Part B: Reactions and Synthesis, 5thEdn., Springer, 2007.

3) J. March, M.B. Smith, March's Advanced Organic Chemistry: Reactions Mechanisms, and Structure, 6thEdn., Wiley, 2007.

4) W. Carruthers, I. Coldham, Modern Methods of Organic Synthesis, Cambridge University Press, 2005.

5) A. Fleming, Frontier Orbitals and Organic Chemical Reactions, Wiley, 1976.

6) R.T. Morrison, R.N. Boyd, S.K. Bhatacharjee, Organic Chemistry, 7thEdn., Pearson, 2011.

7) J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, Oxford University Press, 2004.

8) L. Kuerti, B. Czako, Strategic Applications of Named Reactions in Organic Synthesis, Elsevier Academic Press, 2005.

9) Name Reactions in Heterocyclic Chemistry J. J.Li: Wiley interscience, 2005 10) N.S. Isaacs, Physical Organic Chemistry, ELBS/Longman, 1987.

10)S. Sankararaman, Pericyclic Reactions-A Textbook, Wiley VCH, 2005.

MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Quantum Mechanics and Applications**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C68**

Course Summary & Justification	This course aims to equip students with advanced knowledge of quantum mechanics necessary to conduct research and understand literature.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Quantum theory(Undergraduate level). Strong mathematical skill in					
	Differential Equations and Linear Algebra.					

COURSE OUTCOMES (CO)

	Expected Course Outcome		PSO No.

CO No.	Upon completion of this course, students will be able to;	Learning Domains	
1	Understand the experimental foundation of quantum mechanics	U	1,2
2	To study about the operators and eigen values	U,A,E	1,2,3
3	Able to gather information on time-dependent and time-independent Schrödinger equation	U,R	2,3
4	A detailed study on translational, vibrational, rotational motions	U, A, An, E	3,4
5	To study about the Legendre and associated Legendre polynomials	U,A, An	1,2,3
6	To understand the quantum mechanical operators and Ladder operator method for angular momentum	U,A	4,5
7	Understand the quantum mechanics of hydrogen like atoms and orbitals	U, A, An	1,2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	Experimental foundation of quantum mechanics: Elementary ideas of black body radiation, photoelectric effect and atomic spectra, Need of quantum mechanics, Concept of matter wave, de Broglie relation, uncertainty principle and its consequences, Postulates of Quantum Mechanics: State function or wave function postulate: Born interpretation of the wave function, well behaved functions, orthonormality of wave functions.	**15**	**1-4**

Module 2	Operator postulate: Operator algebra, linear and nonlinear operators, Laplacian operator, commuting and non-commuting operators, Hermitian operatorsand their properties, eigen functions and eigen values of an operator. Eigen value postulate: eigen value equation, eigen functions of commuting operators, Expectation value postulate, Postulate of timedependent Schrödinger equation, conservative systems and time-independent Schrödinger equation	**15**	**5**

Module 3	Translational motion: Free particle in onedimension, particle in a one-dimensional box with infinite potential walls, particle in a onedimensional box with finite potential wallstunnelling,particle in a three-dimensional box, separation of variables, degeneracy. Vibrational motion: One-dimensional harmonic oscillator (complete treatment), Hermite equation (solving by method of power series), Hermite polynomials, recursion relation, wave functions and energies-important features, harmonic oscillator model and molecular vibrations, Rotational motion: Co-ordinate systems, cartesian, cylindrical polar and spherical polar coordinates and their relationships, The wave equation in spherical polar coordinates-particle on a ring, the phi equation and its solution, wave functions in the real form, Non-planar rigid rotor (or particle on a sphere), separation of variables, the phi and the theta equations and their solutions, Legendre and associated Legendre equations, Legendre and associated Legendre	**15**	**6**
	polynomials, Spherical harmonics (imaginary and real forms), polar diagrams of spherical harmonics**.**		

Module 4	Quantization of angular momentum, quantum mechanical operators, corresponding to angular momenta (Lx, Ly, Lz and L2), commutation relations between these operators, Spherical harmonics as eigen functions of angular momentum operators Lz and L2, Ladder operator method for angular momentum, space quantization. Quantum Mechanics of Hydrogen-like Atoms: Potential energy of hydrogen-like systems, The wave equation in spherical polar coordinates: separation of variables-r, theta and phi equations and their solutions, wave functions and energies of hydrogen like atoms, Orbitals: Radial functions, radial distribution functions, angular functions and their plots, Dirac's relativistic equation for hydrogen atom (Elementary idea only), Spin orbitals: Construction of spin orbitals from orbitals and spin functions, spin orbitals for many electron atoms, symmetric and antisymmetric wave functions, Pauli's exclusion principle, slater determinants.	**15**	**7**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **G. Continuous Internal Assessment (CIA)** oInternal Test – MCQ based and descriptive answer type o Seminar Presentation – the students will be given individual topics for seminar presentation o Assignments oQuizzes **H. Semester End examination**

References:

1. D. A Mc Quarrie, Quantum chemistry, 2nd edition, University science books
2. J. P. Lowe, Quantum chemistry, 2nd edition, Academic Press ,1993 3. I. N. Levine, Quantum Chemistry, 5th edition, Prentice Hall, 1999

	MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Organic Chemistry Lab -I**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C69**

Course Summary & Justification	This course is designed to give the student an awareness about the safety measures to be taken in the lab, familiarizing the different glassware and equipments used, separation of the components present in the given binary mixture organic compounds using appropriate separation methods and analyzing the separated components using standard procedures. Students will learn how to apply common laboratory techniques to determine the structure, reactivity and analysis of organic compounds. Preparation of different organic molecules from simple molecules is also included in the course. They will become familiar with the nomenclature and behavior of organic functional groups through reactions and instrumental analysis. Students will also be taught tools such as Chem Draw / Chem sketch which will be very handy in their future studies and career.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours

		0	0	60	40	100
Pre-requisite	Knowledge in named reactions in organic chemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To study general methods of separation and purification of organic compounds	U, An	2,3
2	To conduct separation of organic binary mixtures by chemical/solvent separation methods	U, A, An	4,5
3	Should be able to purity assessment of the components by TLC	U, A, An	5,6
4	To be able to draw the structures and generate the IR and NMR spectra of the substrates and products of named reactions	U, A	3,4,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	**General methods of separation and purification**of organic compounds such as: 1. Solvent Extraction 2. Soxhlet Extraction 3. Fractional crystallization 4. TLC and Paper Chromatography 5. Column Chromatography 6. Membrane Dialysis 6. Separation of Organic binary mixtures by chemical/solvent separation methods, 7. Quantitative separation of organic mixtures by column chromatography – Purity assessment of the components by TLC.	**15**	**1,2,3**

Module 2	Using ChemDraw, Symyx Draw and Chemsketch draw the structures and generate the C 13 and H1 NMR spectra of the substrates and products in the following reactions: (a) Dieckmann condensation (b) Baeyer Villiger oxidation (c)Benzilic acid rearrangement	**15**	**4**
Module 3	Draw the structures and generate the C 13 and H1 NMR spectra of the substrates and products in the following reactions: (a) Aldol condensation (b) Cannizaro reaction (c) Pinacol – Pinacolone rearrangement using ChemDraw, Symyx Draw and Chemsketch	**15**	**4**
Module 4	Multi step synthesis and Infra Red, NMR and UV-Visible Spectroscopy of organic compounds	**15**	**3,4**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** **1.** Direct Instruction: Lecture, Explicit Teaching, E-learning **2.** Interactive Instruction:, Active co-operative learning, Authentic learning
Assessment Types	**Mode of Assessment** **E. Continuous Internal Assessment (CIA)** oTwo internal tests oLab skill oAttendance oViva voce oLab record **F. Semester End examination**

References:

1. A. I. Vogel, A Textbook of Practical Organic Chemistry, Longman, 1974
2. A. I. Vogel, Elementary Practical Organic Chemistry, Longman, 1958
3. F. G. Mann, B. C Saunders, Practical Organic Chemistry, 4th Edn. , Pearson Education India, 2009
4. R.Adams, J. R.Johnson, J. F.Wilcox, Laboratory Experiments in Organic Chemistry, Macmillan, 1979

MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Introductions to Nanomaterials**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E52**

Course Summary & Justification	This course emphasis the chemistry of Nanomaterials in detail and to explore the wide application. Also, this course aims to; • Understand and use the properties of Nano-materials in diverse fields. • Gain knowledge about the Nanomaterials, their properties, behaviour, interaction and use of them over many disciplines of science. • The emphasis of the course is to understand the physics of Nanomaterials in detail and to explore the wide application. Highlights of the course is to provided virtual way of understanding the courses materials. Specially the application-based approach.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		20	40	0	20	80
Pre-requisite	Understanding of nanomaterials (Undergraduate level)					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand and use the properties of Nano-materials in diverse fields.	U	1,2
2	Gain knowledge about the Nanomaterials, their properties, behaviour, interaction and use of them over many disciplines of science.	U, A	1,2,7,8
3	Understand the physics of Nanomaterials in detail and to explore the wide application.	U, R	1, 2,3,5,7
4	Understand the constituents of matter, nanomaterials, properties and usefulness.	U	1, 2, 7
5	Able to learn how to understand the basic behaviour of Nanomaterials.	U	1,2,3,7
6	Understand size and shape dependent properties of Nanomaterials.	U, A	1,2,3,7
7	Gain knowledge about classification of Nanomaterials	U, An	1,2,3,7
8	Deep understanding on surface characteristics of Nanomaterials	U, A, An	1,2,7
9	Able to understand different surface energy minimization techniques.	U, A	1,3,4
10	Able to use the knowledge for higher study and research.	U, A	1,2,3
11	Able to explore the possible physics research, their applications in various fields	U	1,2,3,5,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	**Introduction:** Feynmann's vision on nanoscience & technology, bulk vs nanomaterials, natural and synthetic nanomaterials, Quantum confinement in nanostructures- size dependent physical	**10**	**1-4**

	phenomena in semiconductor and metal nanoparticles		
Module 2	Classification of nanostructures, 0D, 1D and 2D nanostructures, Visualization of nanostructures and techniques related.	**10**	**4-7**
Module 3	**Surface Energy**Surface energy and surface stressorigin and estimation of surface energy, Surface Energy minimization:Sintering Ostwald ripening and agglomeration, Energy minimization by Isotropic and anisotropic surfaces	**10**	**8,9**
Module 4	Surface energy and surface curvature, Surface energy stabilization, electrostatic stabilization, steric stabilization, electro-steric stabilization.	**10**	**10,11**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **I. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **J. Semester End examination**

References:

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao, Imperial college Press, (2006)
2. Nanomaterials and Nanochemistry by C.Brechignac, P. HoudyM.Lahmani Springer-Verlag (2007)
3. Materials Science and Engineering-An Introduction, William D.Callister, (Wiley, 2007)

MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Design, synthesis and fabrication of nanomaterials**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E53**

Course Summary & Justification	The course should give a basic introduction to chemical and physical principles in the synthesis of inorganic nanostructured materials. In addition, basic principles of finite size effects as well as fundamental physical and chemical properties of nanomaterials will be covered. The course discusses the kinetics of nucleation and growth of nanoparticles. Mechanism for nucleation and crystal growth along with strategies to control particle size (distribution) also be discussed. The course will also cover different methods for synthesis and characterization of different nanostructures and nanostructured bulk materials.By the end of the course, students will understand the fabrication, characterization, and manipulation of nanomaterials.This course describes the most recent advances in the synthesis, fabrication and characterization of nanomaterials.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		20	40	0	20	80

Pre-requisite	Understanding of Solid state (Undergraduate level), Basics of Introduction to Nanomaterials and general knowledge in chemistry, physics and material science

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	At the end of the course the students should; Describe different mechanisms for nucleation and growth of amorphous and crystalline nanoparticles in relation to the thermodynamic driving force and effective parameters.	U	1,7
2	Quantify nucleation and growth rates for nanoparticles.	U,A	1,2,7
3	Suggest ways of controlling particle size, particle size distribution and morphology based on changes in important system parameters and choice of method.	U,R	1,3,7
4	Understand how surface functionalization can alter end use/applications of nanomaterials	U	1,2,3
5	Understand the fundamentals of characterization techniques most frequently used for studying nanostructures in solution, as well as nanoparticles and catalytic surfaces.	U	3,4,5,6
6	Describe several synthesis methods for fabrication of inorganic nanoparticles, one-dimensional nanostructures (nanotubes, nanorods, nanowires), thin films, nanoporous materials, and nanostructured bulk materials.	U,A	4,5,6
7	The student should have a theoretical background within synthesis/fabrication of nanomaterials which makes he/she prepared for later literature studies and laboratory work within the field.	U, An	4,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.

Module 1	**Fabrication of nanostructures** Bottom-up approaches for nanostructure fabrication: - Selfassembly,Top down approaches for nanostructure fabrication- Lithography- Photolithography- Laser lithography and SPM based lithography (AFM & STM) and nanomanipulation.	**10**	**1,2,3**
Module 2	**Physical Methods Introduction-** Spontaneous growth, Evaporation condensation growth, fundamentals of evaporation condensation growth.	**10**	**2,3**
Module 3	Vapor–Liquid-Solid (VLS) growth, SWCNT and MWCNT growth mechanisms, Physical Vapor deposition techniques (PVD): Sputtering & Evaporation, Atomic layer deposition	**10**	**4,5**
Module 4	Chemical vapor deposition method (CVD), Molecular beam epitaxy(MBE), Electrospinning, Laser ablation, Laser pyrolysis, Ball Milling	**10**	**6,7**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** K. **Continuous Internal Assessment (CIA)** oInternal Test – MCQ based and descriptive answer type o Seminar Presentation – the students will be given individual topics for seminar presentation o Assignments oQuizzes L. **Semester End examination**

References:

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao, Imperial college Press, (2006)

2.An introduction to Electrospinning and Nanofibers by Seeram Ramakrishna, KazutoshiFujihara, Wee Eong Tee, Teck Cheng Lim, Zaveri Ma, World Sci. Pub. Ltd. Singapore, 2005

3. Springer Handbook of Nanotechnology - Bharat Bhusan· Publisher: Springer-Verlag (15 May 2006)
4. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. Publisher: CRC Press (15 December 2008)

MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Drug design and Medicinal chemistry**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E54**

Course Summary & Justification	This course aims to impart basic knowledge on the important terminology in medicinal chemistry, drug, pharmacy, pharmaceutics, toxicology, pharmacodynamics agents, pharmacophore, pharmacodynamics, metabolites and anti-metabolites, and chemotherapy. Through this learning, it is possible to acquire types of drugs on the basis of therapeutic action nomenclature of drugs and difference between drugs and medicines. It will help the students to know the mechanism of chemotherapeutic actions, biological defences, chemical defenses. Learning this course will provide a strong foundation in drug design and development, concept of prodrugs and soft drugs. This course also provides a detailed study on drug absorption, enzymes as drug targets. Introduction to molecular modeling, molecular mechanics, concepts of virtual screening and topological drug classification.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		20	40	0	20	80

Pre-requisite	Basicknowledgeaboutdrugs, drugdesignandcomputeraideddrugdesign

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the important terminology in medicinal chemistry, drug,Pharmacy, and pharmaceutics, mechanism of chemotherapeutic actions and classification of drugs	U	1,7
2	Learn the procedure followed in drug design, drug discovery without lead and development of drug	U,A	1,2,3 ,7
3	Gather information about prodrugs and soft drugs in detail	U,R	2,3,7
4	To understand the drug absorption, drug removal from kidneys and liver	U	1,2,7
5	Gather information about enzymes and receptors as drug targets	U	1,2,7
6	To estimate the CFSE of any complex and predicts low spin/high spin nature	U,A	3,7
7	Able to study molecular modelling, ligand preparation, and molecular mechanics and concepts of virtual screening	U, An	6,7
8	Should be able to understand computational Protein-Ligand docking Techniques with the help of docking servers, TypesRigid Docking, Flexible or induced fit Docking.	U, A, An	5,6,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	**Concepts of Medicinal Chemistry**: Important terminology in medicinal Chemistry, Drug, Pharmacy, Pharmaceutics, Toxicology, Pharmacodynamics agents, Pharmacophore, pharmacodynamics, metabolites and antimetabolites, chemotherapy. Mechanism of chemotherapeutic actions: 1) Biological defenses. 2) Chemical defenses. a) Surface active agents; b) Metabolic antagonism. Assay of Drugs: Chemical Assay, Biological Assay, Immunological Assay, LD50, ED50, IC50 and ID50.	**10**	**1,2**

	Classification and nomenclature of Drugs Classification of drugs on the basis of therapeutic action. Nomenclature of Drugs. Difference between drugs and medicines		
Module 2	Drug Discovery Introduction. Procedure followed in Drug Design. A) Drug Discovery without a lead b) LeadDiscovery. Lead Modification: Drug Design and DevelopmentIdentification of active part: The pharmacophore b) Functional group modification, c)Structure-activity relationship d) Structure modification to increase potency and thetherapeutic index: 1. Homologation; 2. Chain branching; 3. Ring-chain transformation; 4.Bioisosterism Structural Modification to increase oral Bioactivity.1) Electronic Effect; 2) The Hammet equation; 3) Lipophilicity effect. Concept of Prodrugs and soft drugs a) Prodrugs: i) Prodrugs designing, types of prodrugs; ii) Prodrug formation of compoundscontaining various chemical groups, Prodrugs and Drug delivery system b) Soft drugs: i) soft drug cocept; ii) Properties of soft drugs.	**10**	**3,4**
Module 3	Drug Absorption: Drug Entry into the Bloodstream, Oral, Injection, Transdermal, Other Routes, Topical,Distribution: Drug Transport, Blood, Crossing Membranes, Blood–Brain Barrier,Pharmacodynamics: At the Drug Target, Metabolism and Elimination: Drug Removal,Kidneys and Liver. Enzymes as Drug Targets Introduction, Definition, Structure, Case Study	**10**	**5,6**

	Use of a-Helices to Cross Cell Membranes,Types, Mode of Action, Kinetics, Single Substrate, Multiple Substrates, Inhibitors,Reversible and Irreversible, Pharmaceutical Concerns, Mutational Resistance to Inhibitors,Concentration Effects, Metabolism of Drugs. Receptors as Drug Targets Receptors, Similarities and Differences from Enzymes, Classification, Ligand-Gated IonChannels, G-Protein–Coupled Receptors, Tyrosine Kinase–Linked Receptors, NuclearReceptors, Types of Ligands, Agonists, Antagonists, Inverse Agonists, Receptor Theories,Occupancy Theory, Allosteric Theory, Rate Theory, Drug-Target Residence Time.		

Module 4	In-silico and Computer Aided Drug design Introduction to Molecular Modeling, Lipinski's rule of five, Protein preparation, Ligandpreparation, Molecular Mechanics, force fields (Potential energy function), EnergyMinimization Methods, Conformational Analysis. Concepts of Virtual Screening, Druglikeliness, Screening-Counting Schemes, Functional Group Filters, Topological DrugClassification-Pharmacophore Point Filter-Focused Screening Libraries for LeadIdentification, Pharmacophore Screening, Structure-Based Virtual Screening, ProteinStructures, Computational Protein-Ligand Docking Techniques with the help of dockingservers, Types-Rigid Docking, Flexible or induced fit Docking, in silico De Novo design.	**10**	**7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

References:

1. Gringauz, A. Introduction to Medicinal Chemistry: How Drugs Act and Why? John Wiley & Sons (1997).

2. Medicinal Chemistry an Introduction-Gareth Thomas 2nd Ed. Wiley
3. An introduction to Medicinal Chemistry-Graham L. Patrick 5th Ed. Oxford
4. Introduction to Medicinal Chemistry-Alex Gringauz (Wiley)
5. Medicinal Chemistry-Ashutosh Karr
6. Medicinal Chemistry the Modern Drug Discovery Process- Erland Stevens, 2014 byPearson Education.
7. Quintessence of Medical pharmacology-Sujit K. Choudhary, New Central book agency
8. Principles of Medicinal chemistry Vol I & II- S.S Kadam, K.R. Mahadik, K.G. Bothara,NiraliPrakshan.
9. Drug design volumes by Ariens
10. Principles of Drug design by Smith
11. Strategy of Drug design by Brucell
12. The Organic Chemistry of the Drug design and Drug action by Richard B.Silverman

SEMESTER 3

	MAHATMA GANDHI UNIVERSITY **Physical Chemistry**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Physical Chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C70**

Course Summary & Justification	The course describes advanced chemical thermodynamics, application of phase rule to three component systems and principles and classification preparation of solids. It also describes the importance and properties of defects in solid, band theories of solids, and optical, magnetic and electrical properties of solids. This course gives an insights to analysis of advanced electrochemistry.					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Prerequisite	Knowledge in solid state chemistry, thermodynamics and electrochemistry (Graduate level).					

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1.	Understanding of advanced concepts of thermodynamics	U, A	1,2,
2.	Illustrates application of phase rule to three component systems.	U,A	1,2,7
3.	Describes general principles and classification preparation of solids	U	1,7
4.	Describe the importance and properties of defects in solid	U,A	2,7
5.	Describe the free election , band theories of solids	U,R	3,7
6.	Illustrate the optical , magnetic and electrical properties of solids	U	4,7
7.	Design and development of solid materials with prerequired properties based on the structure of solids.	U	2,3,7
8.	Analyze the physical-chemical ,unique optical, electrical, magnetic, thermal, and mechanical properties of solids.	U,A	3,5,6
9.	Understanding and analysis of advanced electrochemistry	U, R	1,2,7
10.	Introduced machine learning approaches in nanoscience	U, I, A	1,7,8
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No.	Module Content	Hrs.	CO. No.
1	**Thermodynamics** Fugacity: Relation between fugacity and pressure, determination of fugacity of gases. Variation of fugacity with temperature and pressure. Activity and activity coefficients. Variation of activity with temperature and pressure. Determination of activity coefficients by electrical methods. Thermodynamics of dilute solutions: Raoult's law, Henry's law. Ideal and non-ideal solutions. Discussion and thermodynamic derivation of the laws of osmotic pressure, cryoscopy and ebullioscopy. Determination of molecular weights. Thermodynamic treatment using the concept of chemical potentials. Phase Rule Studies: Thermodynamic derivation of phase rule; application of phase rule to the two component systems: simple eutectic type, compound formation with congruent melting point and incongruent melting points, systems involving the formation of a continuous series of solid solutions. Application of phase rule to three component systems: Systems of three liquids and systems of two salts and a liquid.	**20**	**1,2**
2	**Solids State and Advanced Materials** Structure – Types and classification of solids, distinction between crystalline and amorphous solids. Unit cell, Bravais lattice, symmetry elements, Miller indices, Bragg's law. Classification of crystals based on bond type and packing in crystals. Imperfections in crystals – Types of defects, stoichiometric defects – Schotky and Frenkel. Nonstoichiometric defects – Metal excess and metal deficient, consequences of metal deficiency defects. Inorganic crystals – Coordination number, radius ratio rule and shapes of ionic crystals.Structure of	**15**	**3,4**

	Pervoskite, spinels and inverse spinels, structures of ionic crystals – AX type: CsCl, ZnS (Zinc blende, Wurtzite), AX2 type: CaF2, TiO2 , Cd2. Experimental methods of crystal structure determination: X - ray diffraction, electron diffraction and neutron diffraction. Comparative study of the three diffraction methods.Electrical, Magnetic and Optical Properties: **Band theory of solids**, significance of band gap, conductors, semi-conductors and insulators. Electrical & optical properties: Electrical conduction in metals. Super conductivity, origin of superconductivity, type I and type II superconductors, meisner effect, Bardeen, Cooper and Schriefer (BCS) theory, Cooper pairs. High temperature superconductors, super conducting cuprates - YBaCu oxide system. Josephson's Junction, conventional superconductors, organic superconductors. Electrical properties: thermoelectric effects, Thomson effects, Peltier effect, seebeck effect, thermocouples, Hall Effect. Magnetic properties: Origin of magnetic dipoles in solids, ferrimagnetic materials, spontaneous magnetization. Dielectric materials, ferro, pyro, piezo electricity and their relations, applications.		

3	**Electrochemistry and Electromotive Force** Theories of ions in solution, Drude and Nernst's electrostriction model and Born's model, Debye-Huckel theory, derivation of Debye-Huckel-Onsager equation, validity of DHO equation for aqueous and non-aqueous solutions, Debye-Falkenhagen effect, conductance with high potential gradients, activity and activity coefficients in electrolytic solutions, ionic strength, Debye-Huckel limiting law and its various forms, qualitative and quantitative tests of Debye-Huckel limiting equation, deviations from the DHLL, ion association, triple ions and conductance minima. Electrochemical cells, concentration cells and activity coefficient determination, liquid junction potential, evaluation of thermodynamic properties, the electrode double layer, electrode-electrolyte interface, different models of double layer, theory of multilayer capacity, electro capillary, Lippmann equation, membrane potential. Fuel cells- Theory and working of fuel cells- methanol fuel cell, H_2-O_2 fuel cell and solid oxide fuel cells. Corrosion and methods of prevention, Pourbaix diagram and Evans diagrams. Overvoltage: hydrogen and oxygen overvoltage, theories of overvoltage, Tafel equation and its significance, ButlerVolmer equation for simple electron transfer reactions, transfer coefficient, exchange current density, rate constants	**15**	**3,4,5**
4	**Machine learning in Nanoscience** Introduction – workflow, Data preprocessing and feature engineering. Basic ML Algorithms – Regression analysis, Naïve Bayes classifiers, Support vector machine (SVM), Decision tree and random forest, Artificial neural network (ANN), Deep learning. Cross-validation.The theoretical basis of assisting DFT with ML. Machine Learning to Analyze Large Data Sets- Analysis of Spectra, Images,	**20**	**6,7**

	and Biological Outcomes, Deconvoluting Components in Mixed Signals, Machine Learning for Metrology of Nanoelectronics. Machine Learning for Design and Discovery- Inverse Design and Adversarial Networks in Nanophotonics, Active Learning, Automated Experimentation, Prediction of new 2D Materials and Heterostructures, Nanoscience to Advance Hardware for Machine Learning, Challenges and Opportunities for Machine Learning and Nanoscience.		

REFERENCES

1. F. Reif, Fundamentals of Statistical and Thermal Physics, Waveland Press, 2009.
2. P. Atkins and J. Paula, Physical Chemistry, 10th Edition, Oxford University Press, Oxford 2014
3. D. A. McQuarrie and J. D. Simon, Molecular Thermodynamics, University Science Books, California 2004
4. R. S. Berry, S. A. Rice and J. Ross, Physical Chemistry, 2nd Edition, Oxford University Press, Oxford, 2007
5. D. A. McQuarrie, Statistical Mechanics, University Science Books, California 2005
6. B. Widom, Statistical Mechanics - A Concise Introduction for Chemists, Cambridge, University Press, 2002
7. F. Reif, Fundamentals of Statistical and Thermal Physics, Waveland Press, 2009.
8. P. Atkins and J. Paula, Physical Chemistry, 10th Edition, Oxford University Press, Oxford 2014
9. D. A. McQuarrie and J. D. Simon, Molecular Thermodynamics, University Science Books, California 2004
10. R. S. Berry, S. A. Rice and J. Ross, Physical Chemistry, 2nd Edition, Oxford University Press, Oxford, 2007
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	MAHATMA GANDHI UNIVERSITY

	Advanced Characterization techniques for Nanomaterials
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Advanced Characterization techniques for Nanomaterials**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C71**

Course Summary & Justification	This course aims to provide a comprehensive overview of characterization of nanoparticles, nanocomposites and hierarchical materials with nanoscale features. Course modules will cover the fundamental scientific principles controlling assembly of nanostructured materials; characterization, measurement and computational tools; new properties at the nanoscale, and existing and emerging applications of nanomaterials. It will introduce advanced nanomaterials characterization techniques, including neutron and X-ray scattering and diffraction, crystal structure analysis, electron microscopy, and nuclear magnetic resonance (NMR).
Semester	**III**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Prerequisite	Introduction to Materials Science (Undergraduate level)					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understanding of mechanical, magnetic and electrical properties measurements.	U	1,2,3,7
2	Provides an insights to characterization, measurement and computational tools.	U,A	4,5,6
3	Understand and analyse new properties at the nanoscale.	U,R	1,2,7
4	Overview of Instrumentation and Sample preparation	U	4,5,6
5	Understanding of principles of advanced characterization techniques.	U,A	4,5,6
6	Understanding of Optical, confocal and Fluorescence microscopes.	U,A,An	4,5,6
7	To learn and analyse Nanostructured materials and applications**.**	U, An	1,2,7
8	Understanding of nano polymers and nanoceramics.	U, A, An	1,2,3,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Mechanical, Magnetic and electrical properties measurement** Nanoindentation principles- elastic and plastic deformation -mechanical properties of materials in small dimensions- models for interpretation of Nanoindentation load displacement curves- Nanoindentation data analysis methods-Hardness testing of thin films and coatings- MD simulation of nanoindentation. Vibration Sample Magnetometer, Impedance Spectroscopy- PPMS, - Measurement of Magnetic and electrical properties of nanomaterials.	15	1,2
2	**Advanced CharacterizationTechniques for Nanomaterials** Principles, Overview of Instrumentation and Sample preparation, Experimental techniques adopted in: Scanning Electron Microscopy: SEM and FESEM -Transmission Electron Microscopy (TEM) – HRTEM- application for analysis of Nanomaterials. Scanning Tunnelling Microscopy (STM), Atomic Force Microscopy AFM)- Non-contact contact- Tapping- conducting mode-.Near Field Scanning Optical Microscopy; Scanning capacitance Microscopy- Scanning Microwave Microscope- Magnetic Force Microscopes MFM)- Chemical Force Microscope (CFM)- Applications for analysis of nanomaterials	15	3,4

3	**Optical and Confocal microscopes** Use of polarized light microscopy – Phase contrast microscopy – Interference Microscopy – hot stage microscopy - surface morphology – Etch pit density and hardness measurements. -Confocal Microscopes - Confocal Raman – Application in Nanobiotechnology. Fluorescence Microscope: Principleand Instrumentation ofThermogravimetry; Differential Thermal Analysis and Differentialscanning calorimetry- Importance of thermal analysis for nanostructures. New Advances and challenges in biological and biomedical materials characterizations- Dynamic light scattering spectroscopy.	**10**	**5,6**

4	**Nanostructured materials and applications** Nano Composites and their Applications, Metal-Metal nanocomposites for nuclear energy applications, Magnetic nanocomposites for Spintronics application, Ceramic nanocomposites for high temperature applications. Nano ceramics: Dielectrics, ferroelectrics and magneto ceramics, Nanopolymers: Preparation and characterization of diblock Copolymer based nanocomposites, Nanoparticles polymer ensembles; Applications of Nanopolymers in Catalysis. Classification of conducting polymers: Intrinsic and extrinsic conducting polymers - Chemical and electrochemical methods of the synthesis of conducting polymers – Applications of conducting polymers in corrosion protection, sensors, electronic and electrochemical energy devices. Miscellaneous applications ofnanotechnology: dental implants,consumer products, biomimetic nanomaterials for tissue engineering,biopolymer tagging, semiconductor quantum dots.	**10**	**7,8**

5	**Societal Implications of Nanoscience and Nanotechnology**Introduction, First industrial revolution to Nano revolution, Milestones of the trajectory of Nanotech. Implications on society, Issues. Green Nanotechnology. Nano Economy, Nano policies and Institutions, Nano Rules and Regulations, Nano ethics. Nanotech and war – Nano Arms race.Public perception and Public involvement in the Nano discourse, Harnessing Nanotechnology for Economic and Social development.	**10 Hrs.**	**6,7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, Interactive instruction: Active co-operative, Presentation by individual student
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

References

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9. Synthesis, Properties, and Applications of Oxide Nanomaterials. José A. Rodríguez, Marcos Fernández-García, Copyright © 2007 John Wiley & Sons, Inc.

10. Advanced Magnetic Structures, David Sellmyer and Ralph Skomski, Springer 2009

11. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor

12. Nanoscale materials -Liz Marzan and Kamat.

13. Physical properties of Carbon Nanotube-R Satio.

14. Polymer nanocomposites: Edited by Yiu-Wing Mai and Zhong-Zhen Yu, First published2006, Woodhead Publishing Limited and CRC Press LLC, USA.

15. Physics of Magnetism - S. Chikazumi and S.H. Charap.

16. Magnetostriction and Magnetomechanical Effects - E.W. Lee.

17. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell.

18. Nano the Essentials, Understanding Nanoscience and Nanotechnology,T. Pradeep, Tanta Mc Graw- Hill Publishing.

	MAHATMA GANDHI UNIVERSITY
	Organic Chemistry II – Advanced Organic Chemistry
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Organic Chemistry II – Advanced Organic Chemistry**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C72**

Course Summary & Justification	The course describes different types of advanced organic reactions and reagents as tools for the synthesis of organic compounds. Principles of protecting group chemistry and retrosynthetic approach towards organic synthesis are also dealt with. Analysis and interpretation of molecular recognition and supramolecular chemistry are also aimed at, along with the understanding of basic principles of green chemistry. The course also aims at acquainting students with the role of reagents and catalysts in organic synthesis.					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Prerequisite	Knowledge in oxidation and reduction reactions in organic chemistry. Fundamental understanding of green chemistry.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1.	To apply the basic oxidation and reduction reactions on organic molecules	U, A	1,7
2.	To describe protective groups in organic synthesis	U, I	1,2,7
3.	To equip the students to synthesize complex natural and unnatural compounds of importance by practicing retrosynthetic analysis	A, C, S	1,3,4, 6 ,7
4.	To analyse the difference in the basic types of synthetic approaches	An, E	6,7
5.	To understand the fundamentals of supramolecular chemistry	U, I	1,2,7
6.	To distinguish and synthesize cation, anion and neutral molecule binding host molecules	U, A, C	6,7
7.	To demonstrate the applications of supramolecular chemistry	U, Ap	1,7
8.	To understand green chemistry and sustainability developments that affect society, environment and economic development	I, Ap	1,2,7
9.	To analyse and compare chemical/industrial processes based on their relative “greenness”	An, E, S	1,2,7
10.	To understand the role of reagents and catalysts in organic synthesis	U, I	2,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Organic Synthesis 1** Metal based and non-metal-based oxidations of a) Alcohols to carbonyls I. Chromium based reagents (John's oxidation, Collin's oxidation, Sarrett oxidation) II. Manganese, aluminium and DMSO based reagents (Swern oxidation, Moffatt–Pfitzner oxidation, Kornblum oxidation, Corey-Kim oxidation) b) Alkenes to epoxides (peroxides/peracids based) - Sharpless asymmetric epoxidation, Jacobsen epoxidation, Shi epoxidation c) Alkenes to diols (manganese and osmium based) - Prevost reaction and Woodward modification d) Alkenes to carbonyls with bond cleavage (manganese based, ozonolysis) e) Alkenes to alcohols/carbonyls without bond cleavage – hydroboration - oxidation, Wacker oxidation, selenium based allylic oxidation	**20**	**1,2**
	f) Ketones to ester/lactones – Baeyer -Villiger oxidation g) Catalytic hydrogenation I. Heterogeneous: Palladium/Platinum/Rhodium and Nickel II. Homogeneous: Wilkinson h) Metal based reductions: Birch reduction, pinacol formation, acyloin formation i) Enzymatic reduction using Baker's yeast		

2	**Organic Synthesis 2** Reagents in organic synthesis: Metal hydride reductions using $NaBH_4$, $LiAlH_4$, DIBAL, Kselectride, Sodium cyanoborohydride, Lithium diisopropylamide (LDA), Dicyclohexyl Carbodiimide (DCC), Gilman's reagent, DDQ Protecting group chemistry: Protection, activation and deprotection process in organic synthesis, protection and deprotection of hydroxyl, carboxyl, carbonyl and amino groups. Retrosynthetic analysis: Basic principles and terminology, Synthesis of aromatic compounds, One group and two group C-X disconnections, One group C-C and two group C-C disconnections. Retrosynthesis of D-luciferin, Functional equivalents and reactivity – Umpolung / polarity inversion reaction (IrelandClaisen rearrangement).	**15**	**3,4**
3	**Advances in Organic Chemistry** Supramolecular Chemistry: Introduction to supramolecular chemistry: Host, Guest, HostGuest complex, Lock and key principle, Preorganisation, Complementarity. Cation binding hosts (Crown ethers, Podands, Calixarenes), Anion binding hosts (Cyclophanes), Naturally occurring cyclic host (Cyclodextrin), Molecular clefts and tweezers, Macrocyclic polyamines (Nitrogen based cyclic hosts), Naturally occurring Siderophores, Rhodopsin – A Supramolecular photonic device. Introduction to Green Chemistry: Twelve principles of Green Chemistry. Green Solvents: Ionic liquids, supercritical CO_2, fluorous solvents,	**15**	**3,4,5**
	PEG. Green Alternatives to Organic Synthesis (Microwave assisted and Sonochemical synthesis) with examples (Synthesis of adipic acid from cyclohexene, synthesis of Ibuprofen).		

4	**Catalysis in Organic Chemistry** Baylis-Hillman reaction, Henry reaction, Nef reaction, Kulinkovich reaction, Ritter reaction, Sakurai reaction, Tishchenko reaction. Brook rearrangement. Tebbe olefination. Metal mediated C-C and C-X coupling reactions: Heck, Stille, Suzuki-Miyaura, Negishi, Sonogashira, Nozaki-Hiyama-Kishi, Buchwald-Hartwig, Ullmann and Glaser coupling reactions. Click reactions (Huisgen 1,3-dipolar addition). Ugireaction, Passerini reaction and Biginelli reaction.	**20**	**6,7**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Active co-operative learning, Library work, E-learning Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** **C. Continuous Internal Assessment (CIA)** ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **D. Semester End examination**

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MAHATMA GANDHI UNIVERSITY

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Physical Chemistry Lab-I**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C73**

Course Summary & Justification	To have hand-on experiences of techniques for verifying physical and chemical properties					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		0	0	60	40	100
Pre-requisite	Bachelors degree in chemistry, with physics and mathematics as subsidiaries.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To conduct the experiment on various instrumental techniques.	A	3,4,6
2	To measure various physical and chemical properties.	A	3,4
3	To describe the principles behind the experiment performed in the laboratory.	Ap	3,4
4	To interpret the experimental results obtained by various techniques.	An	4,5,6
5	To understand the principles behind the experiment performed in thelaboratory.	U	5,6,7
6	The students will acquire knowledge of experimental techniques for controlling the chemical reactions.	C	1,2,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	Adsorption Verification of Freundlich and Langmuir adsorption isotherm Charcoal Acetic acid or Charcoal-Oxalic acid system Determination of concentration of given acid using the isotherm	**15**	**1,2**
Module 2	Phase diagrams Construction of phase diagram of simple eutectics Effect of KCl/Succinic acid on Critical Solution Temperature of phenol water system Construction of phase diagram of three component system with one pair of partially miscible liquids	**15**	**2,3**
Module 3	Distribution law Distribution coefficient of Iodine between an organic solvent and water Determination of the equilibrium constant of the reaction KI+I2→KI3 Determination of unknown concentration of KI	**15**	**4,5**

Module 4	Surface tension 1. Determination of the surface tension of a liquid by (a) Capillary rise method (b) Drop number method (c) Drop weight method 2. Determination of Parachor values 3. Determination of the composition of two liquids by surface tension measurements 4. Determination of CMC of surfactants by surface tension measurements V. Determination of heat of solution from solubility measurements	**15**	**6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** **1.** Direct Instruction: Lecture, Explicit Teaching, E-learning **2.** Interactive Instruction:, Active co-operative learning, Authentic learning
Assessment Types	**Mode of Assessment** **C. Continuous Internal Assessment (CIA)** oTwo internal tests oLab skill oAttendance oViva voce oLab record **D. Semester End examination**

References*:*

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3. J. H. Jensen, Molecular Modeling Basics, CRC Press, 2010
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MAHATMA GANDHI UNIVERSITY

Practical IV- Synthesis and characterization of Nanomaterials

SchoolName	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Practical IV- Synthesis and characterization of Nanomaterials**
Type of Course	**Practical**
Credit Value	3
Course Code	**NSM21C74**

Course Name	**Synthesis of different Nanomaterials**.					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lectur e	Tutorial	Practic al	Other s	Total Learning Hours
		0	0	40	40	80
Prerequisite	Basic knowledge in practical chemistry (Undergraduate level).					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To Acquire sound knowledge about the fundamentals and importance of Nanomaterials.	R, U, An	3,4, 5
2	To compare and correlate various Nanomaterials synthesis techniques.	U, A, An	1,3, 4,5, 6,7
3	To learn the handling of different chemicals (for nanomaterial synthesis), glassware, and precautions to be taken for safety in a chemistry lab	R, U, A	3,4, 5

4	To learn the synthesis of different nanomaterials (biobased nanomaterials, green synthesis of nanomaterials, etc.)	U, A, An, S	4,5
5	To perform experiments individually and to gain knowledge about principles and techniques involved in various experiments (nanomaterial synthesis)	An, A, S, I	5,6, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	Extraction of Nanocellulose, Extraction of Nanochitin, Synthesis of different sized Ag nanoparticles by aqueous method, Synthesis of different sized Au nanoparticles by aqueous method, Chemical synthesis of CdSe Quantum dots with different sizes.	**20**	**1,2,3,4,7**
2	Sol-gel synthesis of ZnO nanoparticles, Green synthesis of ZnO nanoparticles, Coprecipitation synthesis of magnetic (iron oxide) nanoparticles, Synthesis of metal oxide nanotubes, Hydro/Solvothermal synthesis of metal oxide nanostructures of different morphology by varying parameters, Synthesis of SnO_2 nanostructures, Hydrothermal synthesis of TiO2 nanoparticles, Synthesis of Graphene and Graphene Oxide.Synthesis of carbon nanotube, Synthesis of nanosilica, Extraction of organic nanosilica.	**15**	**3,4,5,6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Library work, Tutorials, Demonstrations, Workshops, Virtual laboratory videos

Assessment Types	Mode of Assessment
	A. Lab/Experiment skills **B.** Lab record/Report **C.** Viva-voce **D.** Lab Discipline (participation, punctuality, accuracy) **E.** **Semester End examination**

REFERENCES

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao , Imperial college Press, (2006). Publisher: World Scientific Publishing Company; 2 edition (4 January 2011) ISBN-13: 978-9814324557

2. Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim (Federal Republic of Germany), 1998. Publisher: Wiley VCH (28 May 1998) ISBN-13: 978-3527294435

3. Nanomaterials and Nanochemistry by C. Brechignac.P. Houdy M. Lahmani, Springer-Verlag (2007). (For Unit III-Part I Chapter I)

4. PADINJAKKARA A, Scarinzi G, Santagata G, Malinconico M, Razal JM, Thomas S, Salim NV. Enhancement of Adhesive Strength of Epoxy/Carboxyl-Terminated Poly(butadiene-coacrylonitrile) Nanocomposites Using Waste Hemp Fiber-Derived Cellulose Nanofibers. ACS Industrial & Engineering Chemistry Research. 2020, 59, 23, 10904-10913. https://pubs.acs.org/doi/abs/10.1021/acs.iecr.0c01053

Supplementary/ Suggested reading

1. NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) ISBN-13: 978-0-07-061788-9

2. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. Publisher: CRC Press (15 December 2008) ISBN-13: 978-1420047790

	MAHATMA GANDHI UNIVERSITY **Nanotechnology in Energy**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**

Course Name	**Nanotechnology in Energy**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E55**

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	The module encompasses a detailed exposure to energy challenges, development and implementation of renewable energy technologies. Nanotechnology enabled renewable energy technologies are also be discussed (Module 1)	U, A	1,2,7
2	This module discusses Nanomaterials for Energy Storage Systems. The student will able to understand principles and material design of different nanostructured carbon-based materials. Current status and future trends on energy storage	U, A	1,2,3,7
	systems are also discussed. (Module 2)		
3	This module is to designed to help the students to provide adequate knowledge regarding nanomaterials in fuel cells, hydrogen Storage, thermoelectric materials (in nano scale), supercapacitors (Module 3).	An, E	2,3,7
4	Understanding of application of nanomaterials for hydrogen storage and photocatalysis.	E	2,3,4,5
5	This module gives an insights of role of various nanomaterials for Photovoltaic Solar Energy Conversion Systems.	An, E	2,6,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Renewable Energy Technology** Energy challenges, development and implementation of renewable energy technologies, nanotechnology enabled renewable energy technologies, Energy transport, conversion and storage- Nano, micro, and poly crystalline and amorphous Si for solar cells, Nano-micro Si-composite structure, various techniques of Si deposition	20	1,2
2	**Nanomaterials for Energy Storage Systems** Issues and Challenges of functional Nanostructured Materials for electrochemical Energy Storage Systems, Primary and Secondary Batteries (Lithium ion Batteries), Cathode and anode materials, Capacitor Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Nanostructured Carbon-based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends.	15	3,4
3	**Nanomaterials in Fuel Cell and Storage Technology** Micro-fuel cell technologies, integration and performance for micro-fuel cell systems, thin film and microfabrication methods, design methodologies, micro-fuel cell power sources, Supercapacitors, Specific energy, charging/discharging, EIS analysis.	15	3,4,5
4	**Nanomaterials for Hydrogen Storage and Photocatalysis** Hydrogen storage methods, metal hydrides, size effects, hydrogen storage capacity, hydrogen reaction kinetics, carbon-free cycle, gravimetric and volumetric storage	20	6,7

	capacities, hydriding/dehydriding kinetics, multiple catalytic effects, degradation of the dye, nanomaterials based photocatalyst design, kinetics of degradation.		
5	**Nanomaterials for Photovoltaic Solar Energy Conversion Systems** Principles of photovoltaic energy conversion (PV), Types of photovoltaics Cells, Physics of Photovoltaic cells, Organic photovoltaic cell cells, thin film Dye Sensitized Solar Cells, Quantum dot (QD) Sensitized Solar Cells (QD-SSC), Organic- Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Current status and future trends.	**15**	**5,6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA)
	2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

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1. Twidell. J. and Weir. T "Renewable Energy Resources", E & F N Spon Ltd, 1986.
2. Martin A Green, "Solar cells: Operating principles, technology and system applications", Prentice Hall Inc, Englewood Cliffs, 1981.
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6. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kulwer Acdemic Publishers, Dordrecht, Netherlands (2004).
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9. Hydrogen from Renewable Energy Sources by D. Infield 2004

	MAHATMA GANDHI UNIVERSITY **Advanced Nanobiology**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Advanced Nanobiology**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E56**

Course Summary & Justification	This course comprises the implications and applications of nanostructured materials in medical and health care area. There are four modules for this course and each module covers a detailed explanation from introduction of nanomedicine to advanced applications in different biomedical areas. This course aims to make the learner to understand the nanobio interphase as well as the implications and applications of nanotechnology in health and medicine. The objective of the course content is to create a sound awareness about the recent developments in biomedical sector in the areas of therapeutic and diagnostic strategies through the intervention of Nanotechnology.					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours

		30	30	0	30	90
Prerequisite	Basic knowledge about periodic table and arrangements of elements under Groups and Periods. Basic knowledge in Inorganic Chemistry					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the characteristic properties of bio-derrived nanostructured materials	U, An	1,2,3
2	Understand the biocompatibility issues and pharmacokinetic properties of nanomaterials	U, E	2,3
3	Learn different types of nanomaterials useful for biomedical applications	U,E	4,5,,7
4	Understand the nano-bio interphase and their applications in disease diagnosis and therapy.	U, A	3,,6,7
5	Understand nanopharmaceuticals and different therapeutic approaches by using nanostructured materials	U, A	1,3,7
6	Understand the basics of tissue engineering and regenerative medicine	U,A	1,2,7
7	Different methods for nanoengineered scaffolds and implants for tissue engineering applications	U, A	1,2,3, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.

1	**Introduction to Nanomedicine and Biological Nanostructures:** Introduction of biomolecules (enzymes, proteins, liposomes, antibodies, aptamer), Biologically relevant molecular nanostructures, Protein, Lipids and DNA based nanostructures, DNA–Nanoparticle Conjugates. Interactions of biomolecules and cell with nanomaterials: biocompatibility, surface functionalization of nanomaterials to enhance biocompatibility, nanomaterials biodistribution drug release kinetics and transport mechanism, in biological system, toxicity evaluation and regulatory issues.	**20**	**1,2**
2	**Different types of Nanomaterials and their biomedical applications:** Biomedical applications of nanotechnology, Nano-pharmaceutical materials, Metal nanoparticles, Semiconductor materials, polymeric nanomaterials, Fullerenes, Dendrimers, Cubosomes, Ferritin nanoparticles. Therapeutic potential of nanomaterials, Drug delivery and Controlled release, Nanomicrobicidals, Nanobiosensors; cantilevers as biosensors for molecular diagnosis, carbon nanotubes, FRET based DNA nanosensors, viral nanosensors, Fluorescent Nanoparticles.	**15**	**3,4,5,6**

3	**Nanostructured materials for therapeutic applications:** Nanopharmaceuticals; therapeutic applications of metal nanoparticles, dendrimers, fullerenes, liposomes, nanoshells, Site directed drug delivery and targeted destruction of cancer cells. Photothermal therapy(PTT), Photodynamic Therapy (PDT), Magnetic hyperthermia for the destruction of malignant cells. stem cell therapy, gene therapy, nanomachines for gene delivery, antisense therapy, nanodevices for medicine and surgery.	**15**	**3,4,5**
4	**Nanostructures for Tissue Engineering/Regenerative Medicine**; Basics of regenerative engineering, Factors affecting regeneration, Scaffolds for tissue regeneration, Materials for scaffold fabrication, scaffolds fabrication techniques: particulate leaching, phase separation, three-dimensional pore formation, nano fibers, nanocomposite scaffolds, micro and nanopatterned scaffolds, Engineering of biomaterial to control cell function, Engineering of nanomaterials as implant material,	**20**	**6,7**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **M. Continuous Internal Assessment (CIA)** ➢ Surprise test ➢ Internal Test – Objective and descriptive answer type ➢ Submitting assignments ➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **N. Semester End examination**

REFERENCES:

1. Nanobiotechnology: Bioinspired Devices and Materials of the Future: Oded

seyov and Ilan Levy.

2. Nanomaterials and Nanosystems for Biomedical Applications: M. Reza Mozafari
3. The Handbook of Nanomedicine , Kewal K. Jain
4. BioNanotechnology, Elisabeth S. Papazoglou, Aravind Parthasarathy
5. Biomedical Nanostructures, Kenneth E. Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S. Nair
6. Nanomedicine; Vijay K. Varadan, Linfing Chen, Jining Xie.

	MAHATMA GANDHI UNIVERSITY **Mathematical and Computational Chemistry**
School Name	**School of Nanoscience and Nanotechnology**
Programme	**MSc**
Course Name	**Mathematical and Computational Chemistry**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E57**

Course Summary & Justification	Provide an overview and basic understanding of mathematical, theoretical, and computational chemistry problems and provide practical/programming skills to perform scientific computations to solve chemical problems.					
Semester	3		**Credit**		2	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	30	30	-	30	90
Pre-requisite	Basics of Energy production, conversion and storage systems. (Graduate Level)					

Others- Library, seminar and assignment preparations, test, journal, discussion etc.

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understanding of the basic principles of computational chemistry.	U	1,2,7
2	Performance of simple computational experiments in energy evaluation, potential energy surface modeling, conformational analysis.	U,A	1,2,3,7
3	Skill development to design, perform and analyze chemistry problems using computational tools	U,R	2,3,4
4	Understanding of the molecular orbitals and basis sets and its classification	U	1,5,6,7
5	Describe the electronic properties of molecules by Semiempirical, ab initio methods, Hartree Fock, post Hartree Fock, and density functional methods and its limitations and application	U,A	1,3,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.

1	**Introduction to Computational Quantum Chemistry** Introduction and basic concepts of computational quantum chemistry, potential energy surfaces, conformational search, global minimum, local minima, saddle points. Introduction to LINUX operating system, basic commands in LINUX operating system. Molecular geometry input: Cartesian coordinates and internal coordinates, Zmatrix of polyatomic molecules. General input file format of Psi4/GAMESS/Firefly/Gaussian software, single point energy calculation, geometry optimization, frequency calculation. Molecular dynamics (MD) methods; features of molecular mechanics force field-bond stretching, angle bending, torsional terms, non-bonded interactions and electrostatic interactions. Commonly used force fields- AMBER and CHARMM.	**10**	**1,2,4**
2	**Semiempirical and Ab-Initio Quantum Chemical Methods** Semi-empirical quantum chemistry methods, ab initio quantum chemistry methods: Pauli principle, antisymmetric wave functions and Slater determinants. self-consistent field (SCF) procedure, independent electron approximations, Hartree-Fock approximation, Basic concepts for HartreeFock (HF) method, Restricted Open-Shell Hartree-Fock (ROHF) and Unrestricted Hartree-Fock (UHF) methods. Basis sets and its classification, Slater and Gaussian functions, Pople style basis sets, polarization and diffuse functions,	**10**	**2,3,4**
3	**Post-Hartee Fock methods and Density Functional Theory** Introduction to post-Hartree-Fock methods: Møller-Plesset perturbation theory, Configuration Interaction (CI), Coupled Cluster (CC). Density Functional Theory: foundations, example of functional. The Hohenberg-Kohn theorems, The Kohn- Sham ansatz. The local spin density approximation (LSDA), Generalized-gradient	**10**	**3,4,5**

	approximation (GGAs) , Local Density Approximation, hybrid functionals.		
4	**Numerical methods in Chemistry** Solutions of equations using numerical methods- Newton Raphson's method, Linear algebra, Matrix manipulations including Gauss Jordan and Gauss sidel methods, Numerical solution of differential equation. Precision and Accuracy, Determinate and indeterminate errors, computational error struncation and rounding off errors, algorithm errors-absolute and relative errorsError propagation. Measures of Dispersion – range, arithmetic mean, mean deviation variance and standard deviation – movements – skewness and kurtosis. Interpolation: interpolation for linear fit, linear interpolation in non-linear fit, polynomial interpolation – Lagrange interpolation formula – Application to complex equilibria. Numerical techniques of solving ordinary first order differential equations:- Euler's method, Predictor-corrector method, Rungae Kutta method-application to chemical kinetics.	**10**	**1,6,7**

REFERENCES

1. J. H. Jensen, E. G. Lewars, Computational Chemistry: Introduction to the Theory and Applications of Molecular and Quantum Mechanics, 2nd Edn., Springer, 2011
2. F. Jensen, Introduction to Computational Chemistry, 2nd Edn., John Wiley & Sons, 2007
3. A. R. Leach, Molecular Modelling: Principles and Applications, 2nd Edn., Pearson Education Ltd., 200
4. K. I. Ramachandran, G. Deepa, K. Namboori, Computational Chemistry and Molecular Modeling: Principles and Applications, Springer, 2008
5. A. Hinchliffe, Molecular Modelling for Beginners, 2nd Edn., John Wiley & Sons, 2008

6. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, 2nd Edn., John & Sons, 2004

7. D. C. Young, Computational Chemistry: A Practical Guide for Applying Techniques Real-World Problems, John Wiley & Sons, 2001.

8. E.Kreyszig, Advanced Engineering Mathematics, 10 th Edn., John Wiley and sons, 2011

OPEN COURSE

SEMESTER 4

	MAHATMA GANDHI UNIVERSITY
	Dissertation and viva-voce

School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M.Sc.**					
Course Name	**Dissertation and Viva-Voce**					
Course Credit	**10**					
Type of Course	**CORE**					
Course Code	**NSM21C75**					
Course Summary & Justification	The candidate shall do a research project in any of the research institute. This follows discussion with the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.					
Semester	**IV**					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours

	Library work, lab work, Team work, independent learning	-	-	-	-	-
Pre-requisite						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	At the end of the course the students are expected to		
	To clearly present and discuss the research objectives, methodology, analysis, results and conclusions effectively.	A	2, 3, 4, 5
2	Acquire a comprehensive knowledge of the area subject of study	Ap	1, 7
3	Gain deeper knowledge of methods in the topic of study.	A	6
4	Able to contribute to research and development work.	U	3
5	Undertake independent, original and critical research on a relevant topic.	U	5
6	Able to plan and use adequate methods to conduct specific tasks in given frameworks and to evaluate this work.	U	6
7	Create, analyse and critically evaluate different problems and their solutions.	C	7
8	Gain a consciousness of the ethical aspects of research.	E	6

Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** E-learning, interactive Instruction:, Seminar, Authentic learning, , Library work, laboratory work, Team work, independent learning and Group discussion, Presentation of research work.
Assessment Types	**Mode of Assessment** Evaluation of the presentation by both internal and external examiners.

	MAHATMA GANDHI UNIVERSITY
	Industrial visit / Review

School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M.Sc.**					
Course Name	**Industrial Visit / Review**					
Course Credit	**3**					
Type of Course	**CORE**					
Course Code	**NSM21C76**					
Course Summary & Justification	The Industrial visit/ Review shall be conducted by the School of Nanoscience and Nanotechnology. The students have to visit an industry in the presence of a faculty member of the School during the programme and submit a report on the same at the end of the fourth semester.					
Semester	**IV**					
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Visiting the industry and interacting with the personnel	-	-	-	-	-
Pre-requisite	Basic knowledge in chemistry practicals and industrial chemistry					

1	Demonstrate the applications of chemical concepts and principles learned in classroom.	A	1, 2, 3
2	Illustrate processes and products manufactured in the chemical industries.	A	2, 4
3	Develop awareness of the principles and technological aspects in the chemical industries.	C	2
4	Improve interpersonal skill by communicating directly with industrial personnel.	S	5
5	Aware of the impacts of industrial processes on health, safety, environment and society.	E	6, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Main aim of industrial visit is to provide an exposure to students about practical working environment. They also provide students a good opportunity to gain full awareness about industrial practices. Through industrial visit students get awareness about new technologies.
Assessment Types	**Mode of Assessment** The report shall be evaluated by the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.

	MAHATMA GANDHI UNIVERSITY
	Mini project

School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Mini project**
Course Credit	**3**

Type of Course	**CORE**					
Course Code	**NSM21C77**					
Course Summary & Justification	The candidate shall do a mini project under the guidance of school faculty in relevant area.					
Semester	**IV**					
Total Student Learni ngTim e (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learnin g Hours
	Library work, lab work, Team work, independen t learning	-	-	-	-	-
Pre-requisite						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	At the end of the mini project the students are expected to		
1	To clearly present and discuss the research objectives, methodology, analysis, results and conclusions effectively.	A	2, 3, 4, 5
2	Acquire a comprehensive knowledge of the area subject of study	Ap	1, 7
3	Gain basic knowledge of methods in the area	A	6
4	Able to contribute to research and development work.	U	3

Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** E-learning, interactive Instruction:, Seminar, Authentic learning, , Library work, laboratory work, Team work, independent learning and Group discussion, Presentation of research work.

Assessment Types	Mode of Assessment Evaluation of the presentation by both internal and external examiners.

****Open Courses offered by School of Nanoscience and Nanotechnology**

	MAHATMA GANDHI UNIVERSITY
	Open Course - Nanoscience and Nanotechnology

School Name	**School of Nanoscience and Nanotechnology**
Programme	**M.Sc.**
Course Name	**Nanoscience and Nanotechnology**
Type of Course	**Open course**
Credit Value	**4**
Course Code	**NSM21O-01**

Course Summary & Justification	The open course in Nanoscience and Nanotechnology is offered at School of Nanoscience and Nanotechnology in collaboration with IIUCNN, Mahatma Gandhi University, and provides an overview of nanomaterials, their synthesis, properties, and specific applications of nanotechnology in material science, biomedical fields, electronic devices, modelling and simulation, environmental solutions, and in energy production. The open course program is designed to produce students that can apply fundamental knowledge of physics, chemistry, biology, material science, and computational science, to get fundamental knowledge in how to model and solve problems related to design, synthesis, characterization, fabrication, and optimization of functional nano materials. Recognizing the multidisciplinary nature of the field, the teaching and project guidance will be accordingly delivered by qualified faculty from the School of Nanoscience and Nanotechnology and IIUCNN, including, nano engineering, chemical engineering, chemistry, physics, biology, and materials					
	science divisions.					
Semester	**IV**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial			Total Learning Hours
	Literature survey, independent learning					
Pre-requisite	-					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.

1	To introduce the students to the world of nanoscience and provide knowledge of various synthesized/developed and natural nanomaterials and their possibilities.	U	1,2,7
2	To create understanding of the fundamentals of nanoscience and the properties of nanomaterialswhich are different from their bulk counterparts.	U,A	1,2,3,7
3	To create understanding of Size and shape dependence of properties at nanoscale.	U,R	2,3,7
4	Explain the properties of carbon nanomaterials.	U	2,3,7
5	Outline the structure, properties and applications of nanomaterials	U	3,7
6	Understand the various approaches for nanomaterials synthesis	U,A	5,6,7
7	To understand the applications of nanomaterials in the fields of material science, biomedical fields, electronic devices, modeling and simulation, environmental solutions, and in energy production	U,A	4,5,6
8	Understand the toxicity and environmental Risks of Nanomaterials	U,A	1,2,7
CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	To introduce the students to the world of nanoscience and provide knowledge of various synthesized/developed and natural nanomaterials and their possibilities.	U	1,2,7
2	To create understanding of the fundamentals of nanoscience and the properties of nanomaterialswhich are different from their bulk counterparts.	U,A	1,2,3,7
3	To create understanding of Size and shape dependence of properties at nanoscale.	U,R	2,3,7
4	Explain the properties of carbon nanomaterials.	U	2,3,7
5	Outline the structure, properties and applications of nanomaterials	U	3,7

6	Understand the various approaches for nanomaterials synthesis	U,A	5,6,7
7	To understand the applications of nanomaterials in the fields of material science, biomedical fields, electronic devices, modeling and simulation, environmental solutions, and in energy production	U,A	4,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Fundamentals of Nanoscience and Nanotechnology** General introduction and history of nanomaterials, Feynmann's vision on nanoscience & technology, bulk vs nanomaterials, natural and synthetic nanomaterials. Classification of nanostructures, Zero dimensional, one dimensional two dimensional nanostructures. Size and shape dependant properties and their uniqueness, energy at nanoscale - surface characteristics of nanomaterials, quantum confinement effect. Carbon based nanomaterials; properties and applications of fullerene, carbon nanotube, graphene, carbon onion, nanodiamond. Core-shells, quantum dots, nanoclusters, core-shells, organic, inorganic, hybrid nanomaterials, biomimetic nanomaterials.	**20**	**1,2**

2	**Properties of Nanosmaterials** General Introduction to electronic, optical, magnetic, catalytic, mechanical, and thermal properties of nanomaterials. Fundamental types of electronic nanomaterials. Microelectronics, Band structure- conductor and semiconductor. Electrical conductivity in nanomaterials. Optical and photonic properties: Interaction of light with matter, the surface plasmon – SPR and scattering color generation from nanoparticles and nanostructures. Quantum dots – Optical properties related to quantum confinement. Magnetic Properties: Introduction – magnetic phenomena and their classical interpretation- the nanoperspective. Introduction to nanomagnetism- characteristics of nanomagnetic materials- Magnetization and nanostructures. Mechanical & Thermal properties: Nanomechanics- Introduction- lattice mechanics- linear elasticity relations	**15**	**3,4**

3	**Synthesis and Preparation of Nanomaterials** Understand the principles behind synthesis of nanomaterials such as top down, bottom up approaches, and solid-state synthesis methods. Fabrication of nanomaterials by physical methods: ball milling, physical vapor deposition, sputtering, laser ablation, ion sputtering, laser pyrolysis, molecular beam epitaxy, Langmuir-Blodgett growth, electrospinning. By chemical routes: chemical precipitation and coprecipitation, sol-gel methods, chemical vapour deposition (CVD). General methods for preparation, properties, and characterization of nanoparticle/polymeric blends and its applications. General methods for the preparation of bionanoparticle/polymeric	**15**	**3,4,5**

	blends and its applications. Surface modification of polymeric nanomaterials.		
4	**Characterization Methods and Analytical tools for Nanoparticles** General introduction to spectroscopic techniques, Optical Microscopy, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunnelling Microscopy, Optical Absorption and Emission Spectroscopy,Thermo Gravimetric Analysis, Differential Scanning Calorimetry, Thermomechanical Analysis, X-Ray Diffraction, UV-Visible spectroscopy, Raman Spectroscopy, Dynamic Light Scattering (DLS), Differential Scanning Calorimeter (DSC), Differential Thermal Analyzer (DTA), Contact Angle Analysis, Scanning Probe Microscopy (SPM), X-ray Photoelectron Spectroscopy (XPS), electrochemical characterization measurements, Introduction to LASER spectroscopy and its applications.	**20**	**6,7**

5	**Applications of Nanoscience and Nanotechnology** Applications ofnanostructured materials for clean energy-related applications. Nanomaterials for photovoltaic solar energy conversion systems. Functional nanostructured materials for electrochemical energy storage systems, fuel cells, nanocatalyts, nanomagnetic materials and devices, nano sensors. Applications of nanobiotechnology in tissue engineering, biopolymers for tissue engineering, nanomedicines, wound healing, drug delivery, diagnostic and therapeutic applications of nanoformulations. Applications of nanotechnology in medicine and dentistry. Nanostructured materials for EMI shielding applications. Graphene Functionalization for Applications. Applications of conducting polymer nanocomposites, modeling of advanced nano energy materials, electronic structure of nanoparticles, Modeling, design and simulations of nanostructured materials. Photonic and opto-electronic properties and applications of nanoparticles. Environmental application of nanomaterials, water purification system.	15	3,6

6	**Health, Environmental risk, Toxicology and Safe Handling of Nanomaterials** General introduction to Environmental risk, Toxicology of nanomaterials. Developing Environmental Regulations Pertinent to Nanotechnology, Analyses of Nanoparticles in the Environment, Ecological hazards of nanomaterials. Assessing nanotechnology health risk, treatment of nanoparticles in waste water, nanoparticles in pollution control, Development of sustainable nanotechnology. Toxicology and risk assessment, determination of potential toxicity, nanoparticles in work place, biodistribution and interaction of nanoparticles, nanoparticle dose in humans- issues and challenges.	20	4,7

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** E-learning, interactive Instruction:, Seminar, Authentic learning, , Library work , laboratory work, Team work, independent learning and Group discussion, Presentation of research work
Assessment Types	**Mode of Assessment** Evaluation of the presentation by both internal and external examiners

REFERENCES

1. H. S. Nalwa (Ed.), "Encyclopedia of Nanoscience & Nanotechnology", American Scientific Publishers, California, 2004
2. M. D. Ventra, S. Evoy and J. R. Heflin, “Introduction to Nanoscale Science and Technology”, Kluwer Academic Publishers, 2004.
3. Anke Krueger, Carbon Materials and Nanotechnology, WileyVCH Verlag GmbH & Co. KgaA, 2010.
4. B.P.S. Chauhan (Ed), Hybrid Nanomaterials: Synthesis, Characterization, and Applications,Wiley-VCH Verlag GmbH, 2011.

5. Cao, G., Nanostructures and Nanomaterials Synthesis, Properties, and Applications, Imperial College Press, 2004

6. M. A. Ratner and D. Ratner, "Nanotechnology: A Gentle Introduction to the Next Big Idea", Prentice Hall, 2002.

7. M. D. Ventra, S. Evoy and J. R. Heflin, "Introduction to Nanoscale Science and Technology", Kluwer Academic Publishers, 2004.